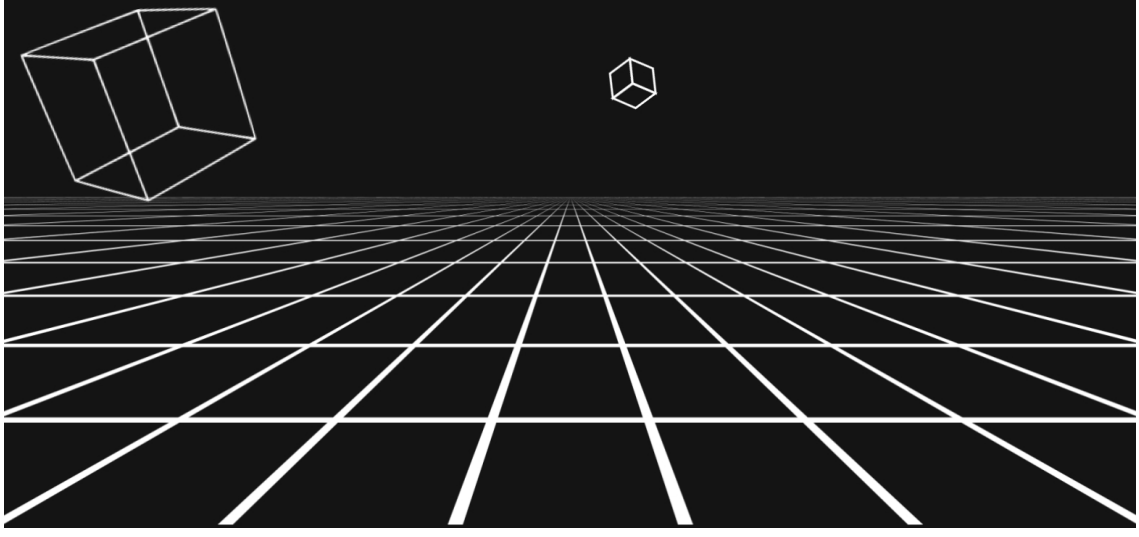
What's the Ultimate Question?

# A MATHEMATICIAN'S JOURNEY

# TO THE EDGE OF THE UNIVERSE

The Cosmic Mystery Tour

BY MANJUNATH.R



# A Mathematician's Journey to the Edge of the Universe:

## What's the Ultimate Question?



"The only true wisdom is in knowing you know nothing."

**– Socrates**

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For any suggestions or concerns, please write to me: **manjunath5496@gmail.com**

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# Preface

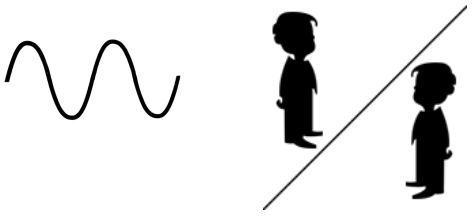


As I embarked on my journey as a mathematician, I never could have imagined where it would take me. From studying the intricacies of abstract algebra to delving into the mysteries of astrophysics, I found myself drawn to the grandest questions of our universe. And with each new discovery, I became increasingly convinced that there must be an ultimate question at the heart of it all.

In this book, I invite you to join me on my journey to the edge of the universe, where we will explore the most fundamental principles that govern our world. Through the lens of mathematics, we will examine the building blocks of reality, from the smallest subatomic particles to the largest structures in the cosmos. We will uncover the hidden symmetries that underlie the laws of nature, and ponder the implications of our most profound discoveries.

But as we venture deeper into the unknown, we will confront the limits of our understanding. We will grapple with questions that defy easy answers, and consider the possibility that some mysteries may forever elude our grasp. And yet, even in the face of uncertainty, I remain convinced that the pursuit of knowledge is a noble and worthwhile endeavor.

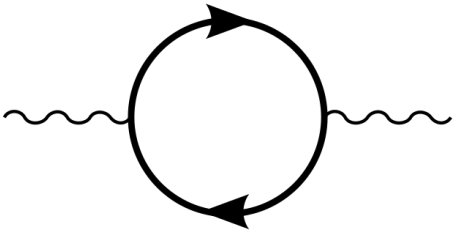
So come, let us journey together to the edge of the universe, and ask: What's the ultimate question?



# Dedication

I **dedicate** this book to everyone who has contributed significantly to our understanding of the universe as a whole, why it is the way it is, and why it even exists.





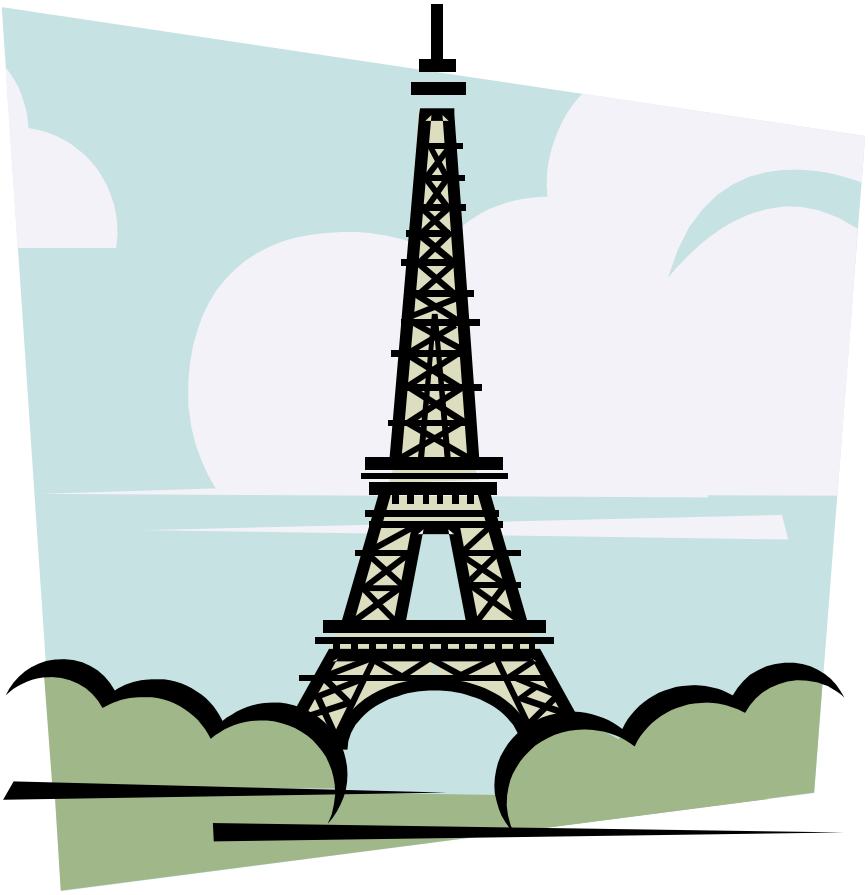
# Acknowledgements

Without the amazing work of some renowned cosmologists and physicists, their creativity, and their inventiveness in thefield of cosmology, this book would not have been accomplished. I would like to use this opportunity to thank my dearest friend and well-wisher "**Lawrence**" for his unwavering support during the **COVID crisis** and for giving me access to all the resources I needed to finish this book. I want to express my gratitude to my family for their support and encouragement as I wrote this book, especially to my **mother**, who has been a tremendous source of inspiration in my life. I owe a lot of gratitude to my mother for teaching me how to be perseverant and strong in life. Finally, I want to emphasize how crucial patience is when writing a book or taking on any other project in life.



"Look up at the stars and not down at your feet. Try to make sense of what you see, and wonder about what makes the universe exist. Be curious."

**– Stephen Hawking**

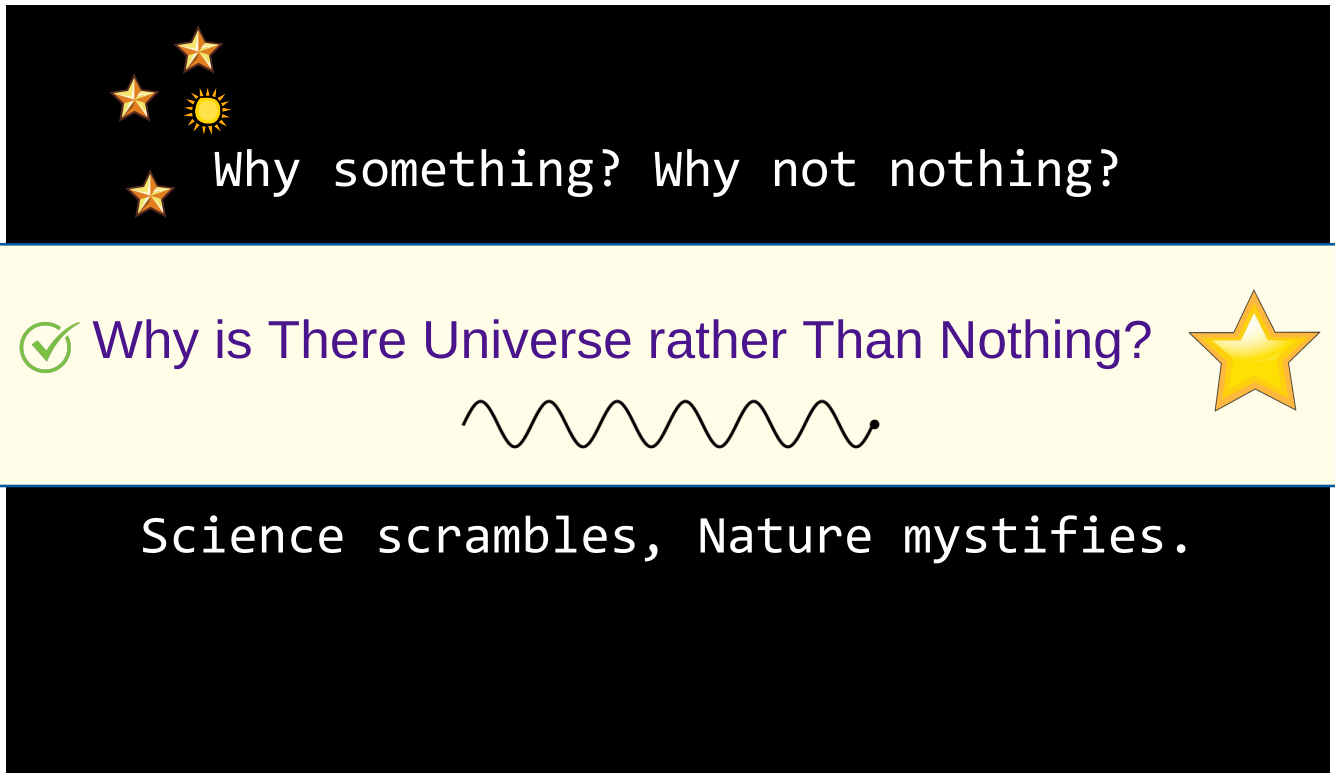


# ✓ Introduction

**We** as a species − who are ourselves mere collections of **elementary particles of nature** – blindly refuse to accept reality as it is − try to comprehend the current state, the beginnings, and the operation of the forces that make up our universe − wonder, seek answers and gazing at the immense heavens above, we have always asked a multitude of questions: What does Matter under Extreme Conditions Look Like and How Does It Act? **What is Dark Matter?** Why is it obscure to us? And what connection does it have to the Big Bang and dark energy? Are there any intellectual beings in the universe than us? What will happen at the end of time? What is Dark Energy? How Has the Universe's Elemental Components changed over Time? **What resides within a black hole?** Does the graviton have mass? **How do Superstrings work?** How can we calculate the universe's size and age? Is it worthwhile to travel to space? What prevents us from going back in time? **Can things travel away from us more quickly than the speed of light?** What are the determinants of particle masses and what sorts of masses do Neutrinos Have? Has planet Earth ever been visited by extraterrestrial species? What does the universe grow into? **How can Quantum Mechanics and Einstein Gravity be made consistent?** What makes space devoid of gravity? What location is the universe's center? How far does the universe extend? **The Big Bang: Is it a Black Hole?** Many others! Though attempting to revolve our collective consciousness around the universe's key questions is generally hard, doing so can be a life-affirming journey and these questions continue to trouble us despite the massive amounts of data coming in from observatories around the globe and from particle physics experiments like the **Large Hadron Collider in Switzerland**, as well as despite the countless hours that we spend in front of a blackboard or running computational simulations.

We do not understand the purpose of the universe, which may raise questions about the cosmic intelligence. However, in the realm of theoretical physics, we are unsure of which theoretical approaches might be correct, despite the fact that they are highly tempting and intriguing to address the topic. Advances in our understanding of basic physics, quantum gravity, and the

ultimate unified theory are necessary for understanding the cosmos. There are numerous things we still don't understand, ranging from the nature of the world to the meaning of dreams. This book is a glimpse into the living story of our universe and a clear, readable and self-contained introduction to the story of how our understanding of the cosmos has evolved significantly over time. It fills the gap and addresses the issues that are important to everyone, or at least to everyone reading this book, and it inspires us to explore the entire cosmos from creation to ultimate destruction, with a wealth of secrets at every turn. **As we read this book, we will learn about the vast variety of celestial objects in the universe, from planetary systems to stars to black holes, and we will get a deeper understanding of astronomy as a discipline.** This book concentrates on presenting the subject from the understanding perspective of cosmology and brings the reader right up to date with curious aspects of cosmology established over the last few centuries. This book assumes **cosmology a journey not a destination** and the advance of knowledge is an infinite progression towards a goal that forever recedes. This book will be of interest to students, teachers and general science readers interested in fundamental ideas of cosmology from the quarks to the physics of the universe.



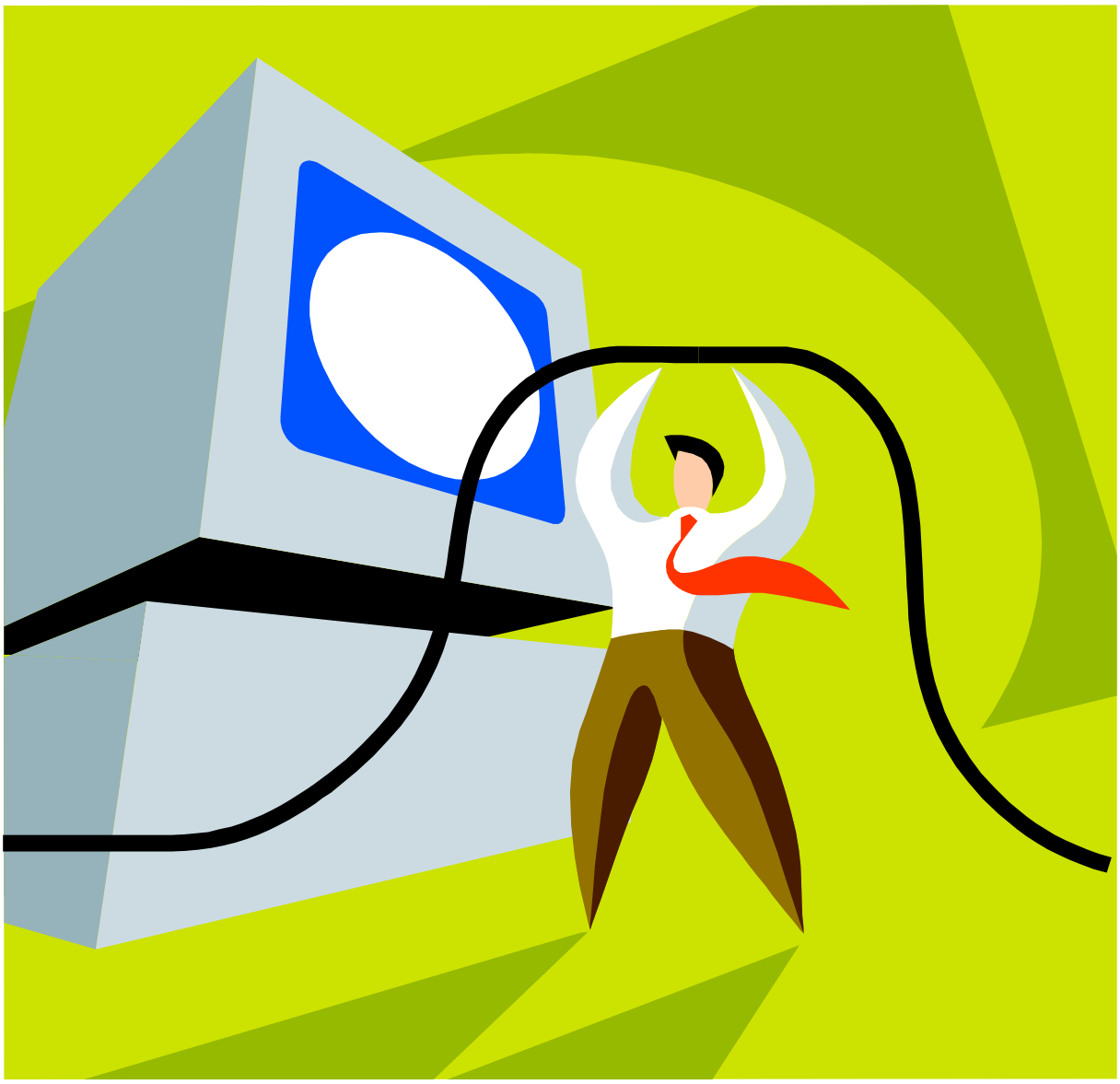


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$$a = \frac{F}{m}$$

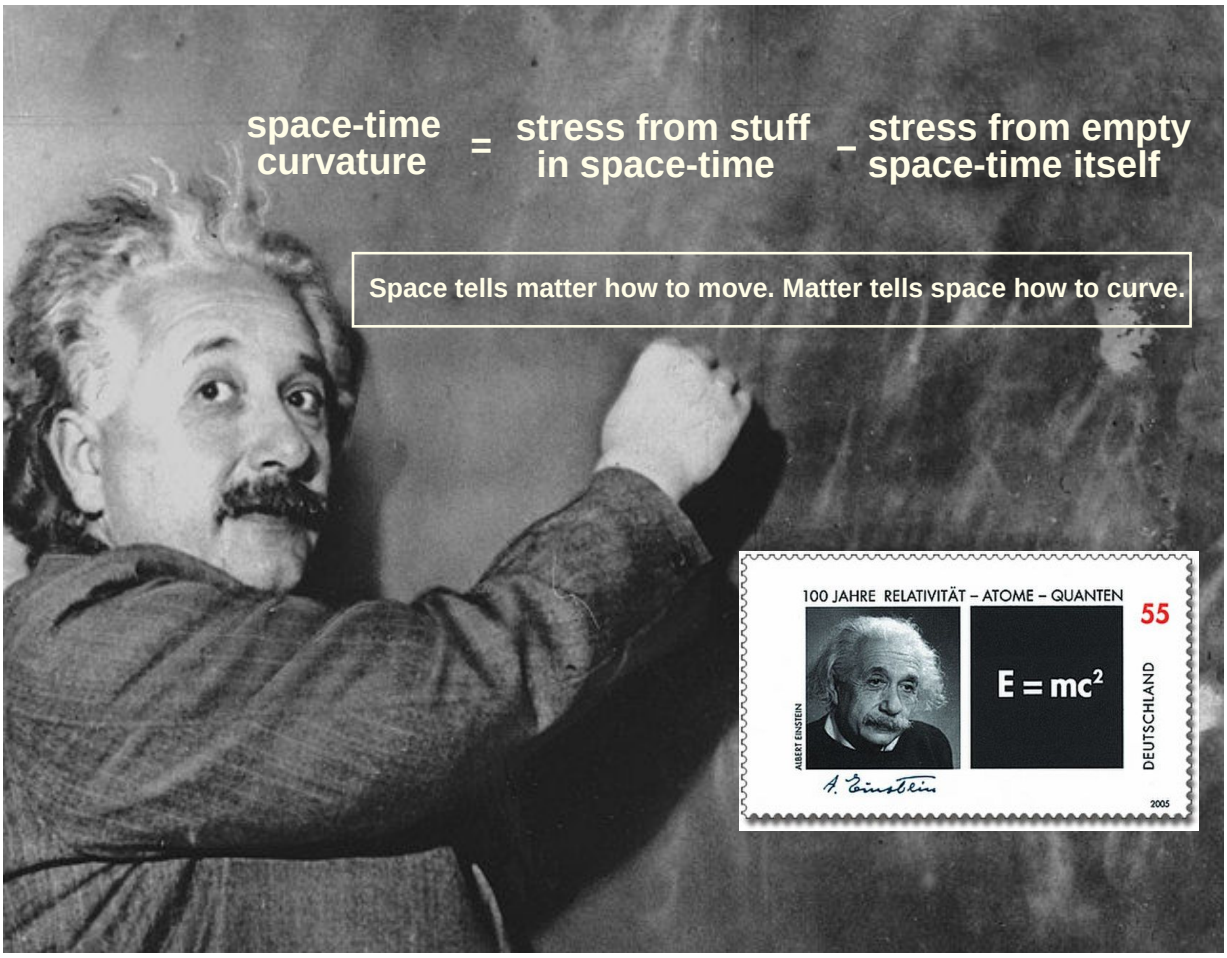
$$E = h\nu$$







$$E = mc^2$$





As long back as history is known, physicists and scientists have investigated a variety of theories over the years to explain our universe and its future. Everything exists in the cosmos. It encompasses all of space as well as the matter and energy that it holds. Even time is a part of it, and we are obviously a part of it. Since the dawn of the history of science from Copernicus **(who took the details of Ptolemy, and found a way to look at the same construction from a slightly different perspective and discover that the Earth is not the center of the universe)** and Galileo to the present, we **(a hoard of talking monkeys who's consciousness is from a collection of connected neurons − hammering away on typewriters and by pure chance eventually ranging the values for the fundamental numbers that would allow the development of any form of intelligent life)** have gazed at the stars and attempted to chart the heavens and still discovering the fundamental laws of nature often get asked:

- Why is there a universe instead of nothing? Was the Big Bang the universe's initial point of origin? Aside than the Big Bang, are there any other theories? What is the evidence for the Big Bang? Are there exotic properties in the geometry of spacetime and does there exist a multiverse? **How numerous are Life Forms in the Universe?** Why is time different from space, where does spacetime come from, and why is it four dimensional?
- Does time exist independently of the universe? How old is the Universe? Is the Universe infinite? **Could the universe have a boundary?** Why are the energies of known particles so small in comparison to the Planck Energy Scale, and Does Supersymmetry Exist?
- Is the cosmos stable? What is Human Consciousness? **How Consistent Is Physics Mathematically?** Is Quarks constricted inside the Particles they constitute every time? What further new Particles need to be found?

We believe that there is more of everything, including stars, galaxies, planets, and other celestial objects, beyond the boundary of the observable universe. However, we do not know the size of the entire cosmos because it cannot be observed. According to **inflation theory**, the universe must be at least $10^{62}$ times larger in circumference than what can be observed. Beginning at Stonehenge and ending with the current crisis in String Theory, the story of this eternal question to uncover the mysteries of the universe describes a narrative that includes some of the greatest discoveries of all time and leading personalities, including Aristotle, Johannes Kepler, and Isaac Newton, and the rise to the modern era of Einstein, Eddington, and Hawking.

# THE HISTORY OF THE UNIVERSE IN 1000 WORDS OR LESS

- **Cosmic Event**

**Big Bang**

**Big Bounce**

**Quantum Fluctuation**



in which our universe was born.

- **Inflation** in which the **Grand Unified Force** was separated into the Four Forces of Nature as We Now Know Them, and the Universe started to Expand to Many Times Its Original Size by a factor of the order of $10^{26}$ over a time of the order of $10^{-33}$ to $10^{-32}$ seconds – Rapid expansion in which the universe cooled from about $10^{27}$ down to $10^{22}$ Kelvin, though not Quite as Quickly. The concept of charge and spin had a central and fundamental position. So, quantities such as charge and spin were correlated with mass.
- **What took place was not destruction; it was transformation.** PARTICLE-ANTIPARTICLE ANNIHILATION in which All the Antiparticles in the Universe Annihilated Almost All the Particles, Creating a Universe Made up of Matter and Photons **(bursts of electromagnetic radiation)** and no antimatter. Several conservation laws were satisfied during the annihilation process, including:

  - Conservation of electric charge.
  - Conservation of linear momentum and total energy.
  - Conservation of angular momentum. 

  The mass that vanished multiplied by the square of the speed of light in a vacuum, was the quantity of energy created by annihilation. Annihilation served as a concrete demonstration of the **half an inch long Albert Einstein's most famous equation:** $E = mc^2$ – a victory of the strength and elegance of fundamental physics.

- **DEUTERIUM AND HELIUM PRODUCTION** in which Many of the Protons and Neutrons in the Early Universe Combined to Form **Heavy Hydrogen** and Helium. **Deuterium** consisted of a proton and a neutron held together by the strong nuclear force and helium consisted of (2 protons + 2 neutrons).
- There was a continuous exchange of virtual photons between the nuclei and the electrons. And the exchange was good enough to produce — what else? — A force **(proportional to a quantity called their charge and inversely proportional to the square of the distance between them)**. And that force pulled the electrons towards the nuclei to form neutral atoms. **RECOMBINATION** in which negatively charged Electrons Combined with Hydrogen and Helium Nuclei, Producing Neutral Atoms. The atoms reflected, absorbed and scattered photons. And there was cosmic microwave background radiation.

The number of protons in the nucleus of a neutral atom was equal to the number of electrons in its orbit. The weak force's range was $10^{-17}$ m, while the strong force's was $10^{-15}$ m. The usual diameter of an atom was about $10^{-10}$ m and hence the range of these forces was lower than atomic sizes. A photon of wavelength "λ" had energy "E" given by: $E = \frac{hc}{\lambda}$ (where h denoted the fundamental physical constant of crucial significance in **quantum mechanics** that defined the quantum nature of energy and c was the cosmic speed limit). There was a continuous exchange of a massless graviton between one matter and the other. And the exchange was good enough to produce a force called gravity. And the dragging pull of gravity caused the expansion rate of the universe to slow down.

- **GALAXY FORMATION** in which the Milky Way Galaxy was Formed – **TURBULENT FRAGMENTATION** in which a Giant Cloud of Gas Fragments broke into Smaller Clouds, which later Became Protostars – **MASSIVE STAR FORMATION** in which a Massive Star was Formed.
- **STELLAR EVOLUTION** in which Stars Evolved and Eventually Died – **IRON PRODUCTION** in which Iron was Produced in the Core of a Massive Star, Resulting in a Disaster called SUPERNOVA EXPLOSION in Which a Massive Star Ended Its Life by Exploding – **STAR FORMATION** in which the Sun was Formed. The **singularities** produced by gravitational collapse occurred only in places, like black holes, where they were decently hidden from outside view by an event horizon.
- **PLANETARY DIFFERENTIATION** in which the Planet Earth was Formed – **VOLATILE GAS EXPULSION** in which the Atmosphere of the Earth was Produced. In addition to providing the oxygen that living organisms required to survive, the atmosphere also shielded them from dangerous Ultraviolet solar radiation – MOLECULAR REPRODUCTION in which Life on Earth was created.
- **PROTEIN CONSTRUCTION** in which Proteins was built from Amino Acids – **FERMENTATION** in which Bacteria Obtained Energy from Their Surroundings – **CELL DIFFERENTIATION** in which Eukaryotic Life had a beginning.
- **RESPIRATION** in which Eukaryotes Evolved to Survive in an Atmosphere with Increasing Amounts of Oxygen – **MULTICELLULAR ORGANISMS CREATION** In Which Organisms Composed of Multiple Cells emerged – SEXUAL REPRODUCTION

in Which a New Form of Reproduction Occurred and with the invention of sex, two organisms exchanged whole paragraphs, pages and books of their DNA helix, producing new varieties for the sieve of natural selection. And the **natural selecti**on was a choice of stable forms and a rejection of unstable ones. And the variation within a species occurred randomly, and that the survival or extinction of each organism depended upon its ability to adapt to the environment. And organisms that found sex uninteresting quickly became extinct. Every organism was endowed with two elements: a set of instructions that tell them how to sustain and multiply themselves, and a mechanism to carry out the instructions. The two elements were **genes** and **metabolism**.

- EVOLUTIONARY DIVERSIFICATION in which the Diversity of Life Forms on Earth Increased Greatly in a Relatively Short Time – **TRILOBITE DOMINATION** In Which **Trilobites** (an extremely successful subphylum of the arthropods that were at the top of the food chain in Earth's marine ecosystems for about 250 million years) Ruled the Earth.
- LAND EXPLORATION In Which Animals First Venture was Onto Land – COMET COLLISION in which a Comet **(cosmic snowball of frozen gases, rock and dust)** smashed the Earth – DINOSAUR EXTINCTION In Which the Dinosaurs **(a group of reptiles that dominated Earth's terrestrial ecosystem for around 245 million years, during the Mesozoic Era)** Died.
- MAMMAL EXPANSION in which Many Species of Mammals was developed – HOMO SAPIENS MANIFESTATION In Which our caveman ancestors Appeared. The grass cells possessed tiny molecular factories, called chloroplasts, which were in charge of a dye sensitized **photochemical redox process** - the conversion of sunlight, water and carbon dioxide into carbohydrates and oxygen. And the eukaryotic cells in a drop of blood contained a different sort of molecular factory, the mitochondrion, which combined respiratory substrates with oxygen to extract useful energy in the form of ATP molecules.
- **LANGUAGE ACQUISITION** in which something called curiosity ensued which triggered the breath of perception and our caveman ancestors became conscious of their existence and they learned to talk and they Developed Spoken Language – **GLACIATION i**n which a Thousand-Year Ice Age Began.
- **INNOVATION** in which Advanced Tools were widely made and Used – **RELIGION** In Which a Diversity of Beliefs, practices and systems emerged pertaining to the worship of

supernatural entity – **ANIMAL DOMESTICATION** in which Humans Domesticated Animals for food, work, clothing, medicine and many other uses.

- **FOOD SURPLUS PRODUCTION** In Which Humans Developed and promoted Agriculture. Most of the food and textiles in the world were provided by agriculture – **INSCRIPTION** In Which Writing was Invented and it allowed the communication of ideas, opinions and plans.
- WARRING NATIONS In Which Nation Battled Nation for Resources – **EMPIRE CREATION AND DESTRUCTION** In Which the First Empire in Human History Came and went – CIVILIZATION In Which Many and Sundry Events Occurred.
- CONSTITUTION In Which a Constitution was Written – **INDUSTRIALIZATION** in Which **Automated Manufacturing** and **Agriculture** Revolutionized the World – WORLD CONFLAGRATIONS In Which Most of the World was at War. In addition to destroying empires, cities and communities, war halted the growth of a country's social and economic structure.
- **FISSION EXPLOSIONS** In Which Humans Developed Nuclear Weapons – **COMPUTERIZATION** In Which Computers were Developed to store and manage data.
- **SPACE EXPLORATION** In Which Humans Began to Explore Outer Space with the aid of astronomy and space technology – **POPULATION EXPLOSION** In Which the Human Population of the Earth Increased at a Very Rapid Pace. Population explosion had a number of negative consequences, including competition for resources, increased environmental contamination, and a lack of energy.
- SUPERPOWER CONFRONTATION In Which Two Powerful Nations Risked it All – **INTERNET EXPANSION** In Which a Network of Computers built to transport a wide variety of information resources and services.
- **RESIGNATION** In Which One Human Quitted His Job – **REUNIFICATION** In Which a Wall went Up and Then Came Down.
- **WORLD WIDE WEB CREATION** In Which a New Medium was Created aiming to provide unrestricted access to a vast array of documents – **COMPOSITION** In Which a Book was Written – **EXTRAPOLATION** In Which Future Events were Discussed.





For millions of years, mankind lived just like the animals. Then something happened which unleashed the power of our imagination. We learned to talk and we learned to listen. Speech has allowed the communication of ideas, enabling human beings to work together to build the impossible. Mankind's greatest achievements have come about by talking, and its greatest failures by not talking. It doesn't have to be like this. Our greatest hopes could become reality in the future. With the technology at our disposal, the possibilities are unbounded. All we need to do is make sure we keep talking.

**— Stephen Hawking**

Ever since the beginning of human civilization, we have not been in a state of satisfaction to watch things as incoherent and unexplainable. While we have been thinking whether the universe began at the big bang singularity and would come to an end either at the big crunch singularity, we have converted at least a thousand joules of energy in the form of thoughts. This has decreased the disorder of the human brain by about few million units. Thus, in a sense, the evolution of human civilization in understanding the universe has established a small corner of the order in a human brain. However, the burning questions still remain unresolved, which set the human race to keep away from such issues. Many early native postulates have fallen or are falling aside – and there now alternative substitutes. In short, while we do not have an answer, we now have a whisper of the grandeur of the problem. With our limited brains and tiny knowledge, we cannot hope to have a complete picture of unlimited speculating about the gigantic universe we live in.

In 1911, fresh from completion of his PhD, the young Danish physicist **Niels Bohr** left Denmark on a foreign scholarship headed for the Cavendish Laboratory in Cambridge to work under J. J. Thomson on the structure of atomic systems. At the time, **Bohr** began to put forth the idea that since light could no long be treated as continuously propagating waves, but instead as discrete energy packets (as articulated by Planck and Einstein), why should the classical Newtonian mechanics on which Thomson's model was based hold true? It seemed to Bohr that the atomic model should be modified in a similar way. If electromagnetic energy is quantized, i.e. restricted to take on only integer values of hυ, where υ is the frequency of light, then it seemed reasonable that the energy associated with the atomic electrons is also quantized (the electrons can possess only certain discrete energy values). However, Bohr's still somewhat vague ideas were not well received by Thomson, and Bohr decided to move from Cambridge after his first year to a place where his concepts about quantization of electronic motion in atoms would meet less opposition. He chose the University of Manchester, where the chair of physics was held by Ernest Rutherford. While in Manchester, Bohr learned about the nuclear model of the atom proposed by Rutherford. To overcome the difficulty associated with the classical collapse of the electron into the nucleus, Bohr proposed that the orbiting electron could only exist in certain special states of motion - called stationary

states, in which no electromagnetic radiation was emitted. In these states, the angular momentum of the electron L takes on integer values of Planck's constant h divided by 2π, denoted by ħ = $\frac{h}{2\pi}$ (pronounced h-bar). In these stationary states, the electron angular momentum can take on values ħ, 2ħ, 3ħ... but never non-integer values. This is known as quantization of angular momentum, and was one of Bohr's key hypotheses. Bohr Theory was very successful in predicting and accounting the energies of line spectra of hydrogen i.e. one electron system. It could not explain the line spectra of atoms containing more than one electron. For lack of other theories that can accurately describe a large class of arbitrary elements to make definite predictions about the results of future observations, we forcibly adore the theories like the big bang, which posits that in the beginning of evolution all the observable galaxies and every speck of energy in the universe was jammed into a very tiny mathematically indefinable entity called the singularity (or the primeval atom named by the Catholic priest Georges Lemaitre, who was the first to investigate the origin of the universe that we now call the big bang). This extremely dense point exploded with unimaginable force, creating matter and propelling it outward to make the billions of galaxies of our vast universe. It seems to be a good postulate that the anticipation of a mathematically indefinable entity by a scientific theory implies that the theory has ruled out. It would mean that the usual approach of science of building a scientific model could anticipate that the universe must have had a beginning, but that it could not prognosticate how it had a beginning. Between 1920s and 1940s there were several attempts, most notably by the British physicist Sir Fred Hoyle (a man who ironically spent almost his entire professional life trying to disprove the big bang theory) and his co-workers: Hermann Bondi and Thomas Gold, to avoid the cosmic singularity in terms of an elegant model that supported the idea that as the universe expanded, new matter was continually created to keep the density constant on average. The universe didn’t have a beginning and it continues to exist eternally as it is today. This idea was initially given priority, but a mountain of inconsistencies with it began to appear in the mid 1960's when observational discoveries apparently supported the evidence contrary to it. However, Hoyle and his supporters put forward increasingly contrived explanations of the observations. But the final blow to it came with the observational discovery of a faint background of microwaves (whose wavelength was close to the size of water molecules) throughout space in 1965 by Arno Penzias and Robert Wilson, which was the "the final nail in the coffin of the big bang theory" i.e., the discovery and confirmation of the cosmic microwave

background radiation (which could heat our food stuffs to only about −270 degrees Centigrade — 3 degrees above absolute zero, and not very useful for popping corn) in 1965 secured the Big Bang as the best theory of the origin and evolution of the universe. Though Hoyle and Narlikar tried desperately, the steady state theory was abandoned.

With many bizarre twists and turns of Humanity's deepest desire for knowledge, super strings − a generalized extension of string theory which predicts that all matter consists of tiny vibrating strings and the precise number of dimensions: ten and has a curious history (It was originally invented in the late 1960s in an attempt to find a theory to describe the strong force). The usual three dimensions of space − length, width, and breadth − and one of time are extended by six more spatial dimensions − blinked into existence. Although the mathematics of super strings is so complicated that, to date, no one even knows the exact equations of the theory (we know only approximations to these equations, and even the approximate equations are so complicated that they as yet have been only partially solved) − The best choice we have at the moment is the super strings, but no one has seen a superstring and it has not been found to agree with experience and moreover there's no direct evidence that it is the correct description of what the universe is. Are there only 4 dimensions or could there be more: (x, y, z, t) + w, v, …? Can we experimentally observe evidence of higher dimensions? What are their shapes and sizes? Are they classical or quantum? Are dimensions a fundamental property of the universe or an emergent outcome of chaos by the mere laws of nature (which are shaped by a kind of lens, the interpretive structure of our human brains)? And if they exist, they could provide the key to unlock the deepest secrets of nature and Creation itself? We humans look around and only see four (three spatial dimensions and one time dimension i.e., space has three dimensions, I mean that it takes three numbers − length, breadth and height− to specify a point. And adding time to our description, then space becomes space-time with 4 dimensions) – why 4 dimensions? Where are the other dimensions? Are they rolled the other dimensions up into a space of very small size, something like a million million million million millionth of an inch − so small that our most powerful instruments can probe? Up until recently, we have found no evidence for signatures of extra dimensions. No evidence does not mean that extra dimensions do not exist. However, being aware that we live in more dimensions than we see is a great prediction of theoretical physics

and also something quite futile even to imagine that we are entering what may be the golden age of cosmology even our best technology cannot resolve their shape.

For n spatial dimensions: The gravitational force between two massive bodies is: $F_G = \frac{GMm}{r^{n-1}}$, where G is the gravitational constant (which was first introduced by Sir Isaac Newton (who had strong philosophical ideas and was appointed president of the Royal Society and became the first scientist ever to be knighted.) as part of his popular publication in 1687 "Philosophiae Naturalis Principia Mathematica" and was first successfully measured by the English physicist Henry Cavendish), M and m are the masses of the two bodies and r is the distance between them. The electrostatic force between two charges is: $F_E = \frac{Qq}{4\pi\varepsilon_0 r^{n-1}}$, where $\varepsilon_0$ is the absolute permittivity of free space, Q and q are the charges and r is the distance between them. What do we notice about both of these forces? Both of these forces are proportional to $r^{n-1}$. So in a 4 dimensional universe (3 spatial dimensions + one time dimension) forces are proportional to $\frac{1}{r^2}$; in the 10 dimensional universe (9 spatial dimensions + one time dimension) they're proportional to $\frac{1}{r^8}$. Not surprisingly, at present no experiment is smart enough to solve the problem of whether or not the universe exists in 10 dimensions or more (i.e., to prove or disprove both of these forces are proportional to $\frac{1}{r^8}$ or proportional to $> \frac{1}{r^8}$). However, yet mathematically we can imagine many spatial dimensions but the fact that that might be realized in nature is a profound thing. So far, we presume that the universe exists in extra dimensions because the mathematics of superstrings requires the presence of ten distinct dimensions in our universe or because a standard four dimensional theory is too small to jam all the forces into one mathematical framework. But what we know about the spatial dimensions we live in is limited by our own abilities to think through many approaches, many of the most satisfying are scientific.

Among many that we can develop, the most well- known, believed theory at the present is the standard four dimensional theory. However, development and change of the theory always occurs as many questions still remain about our universe we live in. And if space was 2

dimensional then force of gravitation between two bodies would have been = $\frac{GMm}{r}$ (i.e., the force of gravitation between two bodies would have been far greater than its present value). And if the force of gravitation between two bodies would have been far greater than its present value, the rate of emission of gravitational radiation would have been sufficiently high enough to cause the earth to spiral onto the **Sun even before the sun become a black hole** and swallow the earth. While if space was 1 dimensional then force of gravitation between two bodies would have been = GMm (i.e., the force of gravitation between two bodies would have been independent of the distance between them).

The **Anthropic principle**, proposed by astronomer **Brandon Carter** in 1974, suggests that our existence in a universe capable of supporting intelligent life is due to a specific selection principle. Without this principle, the conditions necessary for the emergence of complex beings like us would have been drastically different, resulting in a universe where life as we understand it could not have evolved. And if spacial dimensions would have been > than 3, the force of gravitation between two bodies would have been decreased more rapidly with distance than it does in three dimensions. (In three dimensions, the gravitational force drops to $\frac{1}{4}$ if one doubles the distance. In four dimensions it would drops to $\frac{1}{5}$ , in five dimensions to $\frac{1}{6}$, and so on.) The significance of this is that the orbits of planets, like the earth, around the sun would have been unstable to allow for the existence of any form of life and there would been no intelligent beings to observe the effectiveness of extra dimensions.

Although the proponents of string theory (which occupies a line in space at each moment of time) predict absolutely everything is built out of strings (which are described as patterns of vibration that have length but no height or width — like infinitely thin pieces of string), it could not provide us with an answer of what the string is made up of? And one model of potential multiple universes called the M Theory − has eleven dimensions, ten of space and one of time, which we think an explanation of the laws governing our universe that is currently the only viable candidate for a "theory of everything": the unified theory that Einstein was looking for,

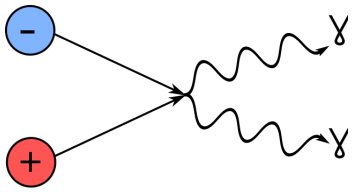
which, if confirmed, would represent the ultimate triumph of human reason– predicts that our universe is not only one giant hologram.

$$e^+ + e^- \rightarrow 2\gamma$$

Many theoretical physicists and scientists of a fast developing science have discussed about mass annihilation at different times. Even a level one graduate know that when an electron and a positron approach each other, they annihilate i.e., destroy each other. This process what a quantum physicists call the mass annihilation. During the process their masses are converted into energy in accordance with $E = mc^2$. The energy thus released manifests as $\gamma$ photons. A positron has the same mass as an electron but an opposite charge equal to +e. The energy released in the form of $2\gamma$ photons during the annihilation of a positron and an electron is therefore: $E = 2h\upsilon = 2m_0c^2$ where $m_0$ is the rest mass of the electron or positron.

$$2h\upsilon = 2m_0c^2$$

Since $\upsilon = c/\lambda$. Therefore:




$$\lambda = \frac{h}{m_0 c}$$

But $\frac{h}{m_0 c} = \lambda_C$ (the Compton wavelength of the electron or positron). Therefore: $\lambda = \lambda_C$ (i.e., wavelength of the resulted gamma photon is = Compton wavelength of the annihilated electron or positron).

$$m_0c^2 = k_B T_P$$

Electrons + positrons → photons

**Once the universe drops below the temperature "$T_P$" ,**
**the electron or positron is effectively removed from the universe.**

$$\lambda \times T_P = \frac{hc}{k_B} = c_2 \text{ (second radiation constant)}$$

$$\lambda_C \rightarrow \frac{h}{m_0 c}$$

Is it a cutoff at which relativistic quantum field theory becomes crucial for its accurate description? The Compton wavelength of the electron or positron characterizes the length scale

at which the wave property of an electron or a positron starts to show up. In an interaction that is characterized by a length scale larger than the Compton wavelength, electron or positron behaves classically **(i.e., no observation of wave nature)**. For interactions that occur at a length scale comparable than the Compton wavelength, the wave nature of the electron or positron begins to take over from classical physics.

$$\lambda_C = \frac{h}{m_{rest}c}$$

The Compton wavelength of a particle is inversely proportional to its mass $\lambda_C \propto \frac{1}{m_{rest}}$, so particles with larger mass have smaller Compton wavelengths, while particles with smaller mass have larger Compton wavelengths. The mass of an electron is much smaller than the mass of a proton or neutron. Therefore, **according to the formula for Compton wavelength**, the Compton wavelength of an electron is much larger than the Compton wavelengths of both the proton and neutron.

If two objects come closer than the **Planck length** (the smallest possible length), they would be so close that their gravitational attraction would be strong enough to form a black hole.

$$m_{rest}c^2 = \frac{hc}{\lambda_C}$$

$$m_{rest}c^2 = h\upsilon_C$$

The Compton frequency of a particle

$$m_{rest} \propto \upsilon_C$$

The higher the rest mass of a particle, the greater its Compton frequency.

**The Compton wavelength of an electron:**

$$\lambda_{C,e} = \frac{h}{m_e c} = \frac{6.62606957 \times 10^{-34}\ \text{Js}}{9.10938291 \times 10^{-31}\text{kg} \times 2.99792458 \times 10^{8}\text{m/s}}$$

$$\lambda_{C,e} \approx 2.426\ 3102389 \times 10^{-12}\ \text{m}$$

**The ratio of the Compton wavelength of an electron to that of a proton is approximately 1836.15. This means that the Compton wavelength of an electron is about 1836 times larger than that of a proton.**

**The Compton wavelength of a proton:**

$$\lambda_{C,p} = \frac{h}{m_p c} = \frac{6.62606957 \times 10^{-34}\ \text{Js}}{1.672621777 \times 10^{-27}\text{kg} \times 2.99792458 \times 10^{8}\text{m/s}}$$

$$\lambda_{C,p} \approx 1.32140985623 \times 10^{-15}\ \text{m}$$

**The Compton wavelength of a neutron:**

$$\lambda_{C,n} = \frac{h}{m_n c} = \frac{6.62606957 \times 10^{-34}\ \text{Js}}{1.674927351 \times 10^{-27}\text{kg} \times 2.99792458 \times 10^{8}\text{m/s}}$$

$$\lambda_{C,n} \approx 1.3195909068 \times 10^{-15}\ \text{m}$$

The Compton wavelength of an electron is approximately 2.426 3102389 × $10^{-12}$ meters, while the Compton wavelength of a proton is approximately 1.32140985623 × $10^{-15}$ meters and the Compton wavelength of a neutron is approximately1.3195909068 × $10^{-15}$ meters.

The **Schwarzschild radius of an electron** can be calculated using formula: $r_S = \frac{2Gm_e}{c^2}$, but it is important to note that the mass of an electron is very small, approximately 9.10938291× $10^{-31}$kilograms. When this value is plugged into the formula, the resulting **Schwarzschild radius** is extremely tiny, approximately about 1.353×$10^{-57}$meters. To put this in perspective, the **size of an electron is about $10^{-15}$meters**, which means that the **Schwarzschild radius** of an electron is much smaller than its **actual size**. This is because the electron is not massive enough to create a gravitational field strong enough to warp space-time to the extent that its escape velocity would reach the speed of light. Hence, the idea of **Schwarzschild radius of an electron** remains strictly hypothetical.

$$r_S \times \lambda\!\!\!^{-}_{C,e} = \frac{2Gm_e}{c^2} \times \frac{\hbar}{m_e c}$$

$$r_S \times \lambda\!\!\!^{-}_{C,e} = 2 \times \frac{G\hbar}{c^3}$$

$$r_S \times \lambda\!\!\!^{-}_{C,e} = 2 \times \text{Planck area}$$

The Schwarzschild radius of an electron times its reduced Compton wavelength is never smaller than a certain quantity, which is known as Planck area.

The product of the Schwarzschild radius of an electron and its reduced Compton wavelength is equal to $5.2242 \times 10^{-70}$ $m^2$. This value is the twice the smallest possible area that can exist in the universe.

$$\lambda = \frac{h}{p}$$

where λ is the wavelength of the particle, p is the momentum and h is the Planck constant

This formula is known as the de Broglie relation, named after the French physicist **Louis de Broglie**, who proposed that all particles, including electrons and atoms, have both wave-like and particle-like properties. The **de Broglie relation** relates the wave-like properties of a particle, as represented by its wavelength, to its momentum, which is a measure of its particle-like properties. The significance of the product of wavelength and momentum being equal to **Planck's constant** is that it provides a fundamental connection between the **wave and particle nature of matter**. This relationship implies that as the momentum of a particle increase, its wavelength decreases, which means that its wave-like properties become less pronounced and its particle-like properties become more dominant. This concept has important implications in **quantum mechanics**, where particles are described by wave functions and their behavior is governed by probabilities rather than definite outcomes. The **de Broglie relation** is a fundamental principle that helps to explain a wide range of phenomena, including the behavior of electrons in atoms, the diffraction of particles through a double-slit experiment, and the wave-particle duality of matter.

In the case of an **electron** orbiting a nucleus in **Bohr's model**, the **electron's angular momentum** (L) is quantized, meaning it can only have certain discrete values. The quantization condition is expressed as $L = n\hbar$, where $n$ is the **principal quantum number**.

$$L = mvr = n\hbar$$

$$2\pi r = n\lambda$$

For a standing wave to form in a Bohr orbit, the circumference of the orbit must be an integral multiple of the electron's wavelength.

Suppose we have a **Bohr orbit** with a radius of 5 nm. We want to find out how many wavelengths of an electron wave can fit around the circumference of the Bohr orbit. In this case, the radius (**r**) is 5 nm, and the electron's wavelength (**λ**) is given as 500 nm. We need to determine the value of **n**, the number of electron's wavelengths that fit around the circumference of the Bohr orbit. The formula $2\pi r = n\lambda$ can be rearranged to solve for n:

$$n = \frac{2\pi r}{\lambda} = \frac{2 \times 3.141 \times 5 \times 10^{-9}\ m}{500 \times 10^{-9}\ m} \approx 0.06282$$

which has a wavelength of 500 nm

Therefore, approximately 0.06282 wavelengths of the electron wave can fit around the circumference of the Bohr orbit with a radius of 5 nm

$$E_n = \frac{n^2 h^2}{8 m_e L^2}$$

The energy of an electron in $n^{th}$ state which is confined in a one dimensional box of length L.

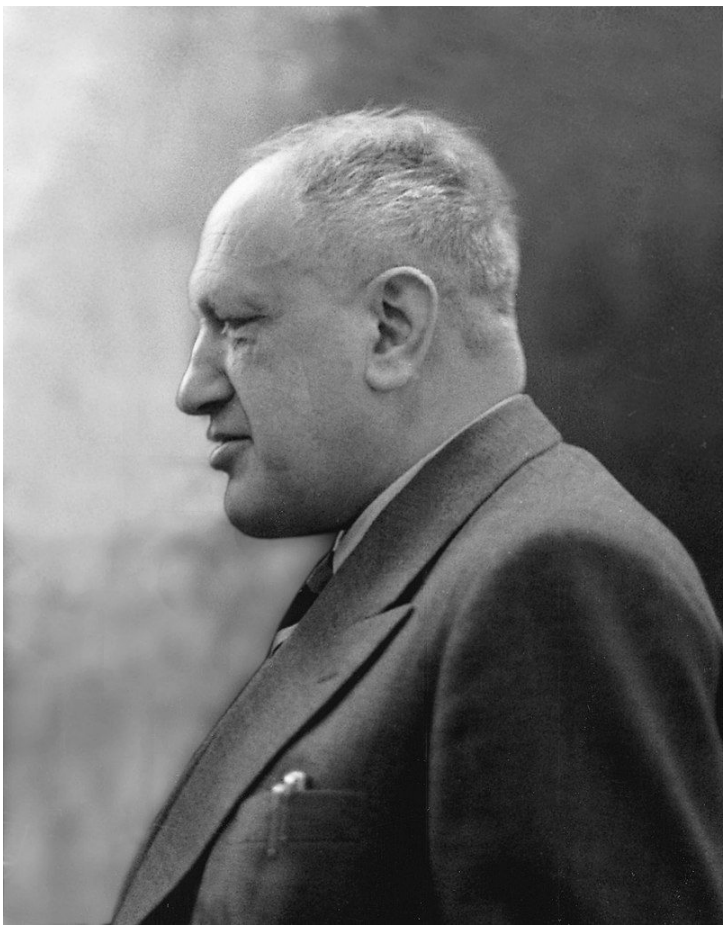
**For any finite value of n:** the value of $E_n$ goes to zero as L goes to infinity.

Let's take an example to illustrate this. Suppose we have an electron confined in a one-dimensional box of length L = 1 nanometer (1 nm). We want to calculate the energy of the electron in the second excited state (n = 2). Using the formula mentioned above, we can plug in the values:

$$E_2 = \frac{2^2 \times (6.626 \times 10^{-34}\ \text{Js})^2}{8 \times 9.109 \times 10^{-31}\ \text{kg} \times (1 \times 10^{-9}\ \text{m})^2}$$

$$E_2 \approx 24.0991744428 \times 10^{-20}\ \text{J}$$

Therefore, the energy of the electron in the **second excited state** which is confined in a one dimensional box of length **1 nm** is approximately **$24.0991744428 \times 10^{-20}$ Joules**.





**Leopold Infeld** was a prominent physicist and mathematician known for his contributions to several areas of physics, including **relativity theory** and **quantum mechanics**. He is perhaps best known for his collaboration with Albert Einstein on the book **"The Evolution of Physics"**, which became a popular and influential work on the history of physics. **Infeld** made significant contributions to the development of the **theory of general relativity**, including the discovery of the singularities in the field equations that would later become known as **black holes**. He also worked on the theory of electromagnetic fields and their interaction with matter, and collaborated with **Richard Feynman** on the **development of the path integral formulation of quantum mechanics**. In addition to his work in physics, **Infeld** was also known for his efforts to promote scientific education and popularize science among the general public. He believed that science should be accessible and understandable to everyone, and wrote several books aimed at a general audience. Overall, **Leopold Infeld** was a highly respected physicist and mathematician who made important contributions to our understanding of the fundamental laws of nature, and worked to share his knowledge and enthusiasm for science with others.

$$a_0 = \frac{\hbar}{\alpha\, m_e c} \approx 5.2917721092 \times 10^{-11} \text{ meters}$$

where $m_e$ is the rest mass of an electron, $\hbar$ is the reduced Planck constant, $\alpha$ is the fine structure constant and c is the speed of light

The **Bohr radius**, denoted by the symbol **"$a_0$,"** is a physical constant representing the distance between the nucleus and the electron in a hydrogen atom in its ground state. Its value is approximately equal to 0.52917721092 Å (angstroms) or $5.2917721092 \times 10^{-11}$ meters. The **Bohr radius** is named after the Danish physicist **Niels Bohr**, who proposed the theory of the hydrogen atom in 1913 based on the concept of quantized energy levels. The **Bohr radius** is an important quantity in atomic physics and is used to calculate various properties of atoms and molecules.

Solar Luminosity = $4\pi \times$ (radius of the Sun) $^2 \times$ Stefan-Boltzmann constant $\times$ (surface temperature of the sun) $^4$

Solar Luminosity = $4\pi \times (6.957 \times 10^8 \text{ m}) \times (5.670374419 \times 10^{-8} \text{ Wm}^{-2}\text{K}^{-4}) \times (5772 \text{ K})^4$

Solar Luminosity $\approx 3.828 \times 10^{26}$ W

The Sun emits approximately $3.828 \times 10^{26}$ joules of energy per second in the form of electromagnetic radiation, making it the most powerful source of energy in our solar system.

The electric potential energy between two electrons separated by distance "r" is given by:

$$E_P = \frac{e^2}{4\pi\varepsilon_0 r}$$

This equation shows that the potential energy between two electrons decreases as their separation distance increases. If the two electrons are very close together, their potential energy will be large, and if they are far apart, their potential energy will be small. The rest mass energy of an electron is given by Einstein's famous equation:

$$E = m_e c^2$$

where E is the energy equivalent of the mass $m_e$, and c is the speed of light in a vacuum, which is approximately 299,792,458 meters per second. The rest mass of an electron is about $9.109 \times 10^{-31}$ kilograms. If we plug this value into the equation above, we get:

$$E = (9.109 \times 10^{-31}\ \text{kg}) \times (299{,}792{,}458\ \text{m/s})^2 \approx 8.187 \times 10^{-14}\ \text{joules}$$

So the rest mass energy of an electron is approximately $8.187 \times 10^{-14}$ joules, or about 0.511 MeV (mega-electron volts). An electron and a positron have equivalent rest mass energies. The combined rest mass energy of an electron and a positron is 1.022 MeV, and it is released when they annihilate one another. This energy can appear as electromagnetic radiation, such as gamma rays or other extremely high-energy photons. This process is a result of the conversion of mass into energy, according to Einstein's famous equation $E=mc^2$.

$$m_e c^2 = \frac{e^2}{4\pi\varepsilon_0 r}$$

$$r = \frac{e^2}{4\pi\varepsilon_0 m_e c^2}$$

Distance of separation at which electric potential energy between two electrons equals rest mass energy of the electron

$$r = \frac{e^2}{4\pi\varepsilon_0 m_e c^2} \approx 2.8179403227 \times 10^{-15}\ \text{m}$$

Classical radius of the electron = Bohr radius × (Fine structure constant) $^2$

## Classical radius of the electron

The value of the **classical electron radius** is approximately $2.8179403227 \times 10^{-15}$ meters, or 2.81femtometers (fm) − which is much smaller than the Compton wavelength of the electron. It represents the size of the electron in classical electrodynamics, which treats the electron as a point particle with no internal structure. The **classical electron radius** is important in many areas of physics, including **atomic physics**, **nuclear physics**, and **condensed matter physics**. For example, it is used in the calculation of the scattering cross-sections of charged particles, such as electrons and protons, by other charged particles, such as atomic nuclei. It is also used in the calculation of the radii of atoms and molecules, as well as in the analysis of the properties of condensed matter systems, such as metals and semiconductors. The significance of the **classical radius of the electron** lies in its relation to the size of the electron in classical physics. The **classical model of the electron** assumes that the electron is a point-like particle with a definite position and momentum at any given time. However, this model fails to explain some of the phenomena observed in the microscopic world, such as the behavior of electrons in an atom. In **quantum mechanics**, the electron is described as a wave function that gives the probability distribution of finding the electron at a particular location. The size of the electron in quantum mechanics is not well-defined and depends on the probability distribution of its wave function. The **classical radius of the electron** provides an estimate of the order of magnitude of the electron's size, but it is not a precise value.

**The electrical force between two electrons separated by distance "r" is given by:**

$$F_1 = \frac{e^2}{4\pi\varepsilon_0 r^2}$$

**The electrical force between two Planck charges separated by distance "r" is given by:**

$$F_2 = \frac{q_{Planck}^2}{4\pi\varepsilon_0 r^2}$$

$$\frac{F_1}{F_2} = \frac{e^2}{q_{Planck}^2} = \frac{e^2}{4\pi\varepsilon_0 \hbar c} = \alpha$$

The **fine structure constant**, denoted by the symbol α (alpha), is a dimensionless physical constant that characterizes the strength of the electromagnetic interaction between charged particles. The **fine structure constant** has a numerical value of approximately $\frac{1}{137}$, which makes it a fundamental constant of nature. It appears in a variety of physical phenomena, including the spectral lines of atoms, the **Lamb shift** in atomic spectra, and the anomalous magnetic moment of the electron. The **fine structure constant** is also related to the **coupling strength of the electromagnetic force** between charged particles. A **larger value of α** corresponds to a stronger electromagnetic force, while a **smaller value** corresponds to a weaker force. In addition, the **fine structure constant** is also related to the strength of the strong and weak nuclear forces, and is a key parameter in theories of particle physics and cosmology. The precise value of the fine structure constant is known with high accuracy, and its value is fundamental to our understanding of the behavior of matter and energy at the atomic and subatomic level. Any variation in the value of α over time or in different regions of space could have significant implications for the laws of physics and the structure of the universe.

**The gravitational force between two electrons separated by distance "r" is given by:**

$$F_1 = \frac{Gm_e^2}{r^2}$$

**The gravitational force between two Planck masses separated by distance "r" is given by:**

$$F_2 = \frac{Gm_{Planck}^2}{r^2}$$

$$\frac{F_1}{F_2} = \frac{m_e^2}{m_{Planck}^2} = \frac{Gm_e^2}{\hbar c} = \alpha_G$$

## Gravitational coupling constant of an electron

**$(1.7518 \times 10^{-45})$**

### Newton's law of gravitation:

**Newton's law of gravitation** is significant because it provides a mathematical understanding of the force of gravity between any two objects in the universe. This law helped to revolutionize our understanding of the cosmos and has been used to explain a wide range of phenomena, from the orbits of planets to the tides on Earth.

$$F_G = \frac{Gm_1m_2}{r^2}$$

$$F_G \propto \frac{m_1m_2}{r^2}$$

G → Proportionality constant

$m_1 = m_2 = 1kg$

$r = 1m$

$$F_G = G$$

The universal gravitational constant is numerically equal to the Gravitational force of attraction between two unit masses placed at a unit distance apart.

Because $E=mc^2$:

$$F_G = \frac{GE_1E_2}{c^4\, r^2}$$

$$F_G \propto \frac{E_1E_2}{r^2}$$

$E_1 = E_2 = 1J$

$r = 1m$

$$F_G = \frac{1}{F_{Planck}}$$

The reciprocal of Planck force is numerically equal to the Gravitational force of attraction between two unit energies placed at a unit distance apart.

The **position-momentum uncertainty principle** states that the more precisely the position of a particle is known, the less precisely its momentum can be known, and vice versa. Mathematically, this principle can be expressed as:

$$\Delta x\, \Delta p \geq \frac{\hbar}{2}$$

where $\Delta x$ represents the uncertainty in the particle's position, $\Delta p$ represents the uncertainty in its momentum, and $\hbar$ is reduced Planck's constant.

The **energy-time uncertainty principle** states that the more precisely the energy of a particle is known, the less precisely the time at which it is measured can be known, and vice versa. Mathematically, it can be expressed as:

$$\Delta E \, \Delta t \geq \frac{\hbar}{2}$$

where $\Delta E$ represents the uncertainty in the energy of the particle, $\Delta t$ represents the uncertainty in the time at which it is measured, and $\hbar$ is reduced Planck's constant.

These **uncertainty principles** have far-reaching implications in quantum mechanics, and they have been shown to be an inherent property of nature at the quantum level. They are also a key concept in understanding the limits of measurement and the fundamental nature of the universe.

$$\Delta x \, \Delta p \geq \frac{\hbar}{2}$$

$$\Delta E \, \Delta t \geq \frac{\hbar}{2}$$

$$\frac{\Delta p}{\text{Planck momentum}} \geq \frac{\text{Planck length}}{\Delta x}$$

$$\frac{\Delta E}{\text{Planck energy}} \geq \frac{\text{Planck time}}{\Delta t}$$

$$\Delta x \, \Delta p \geq \frac{\text{Planck length} \times \text{Planck momentum}}{2}$$

$$\Delta E \, \Delta t \geq \frac{\text{Planck energy} \times \text{Planck time}}{2}$$

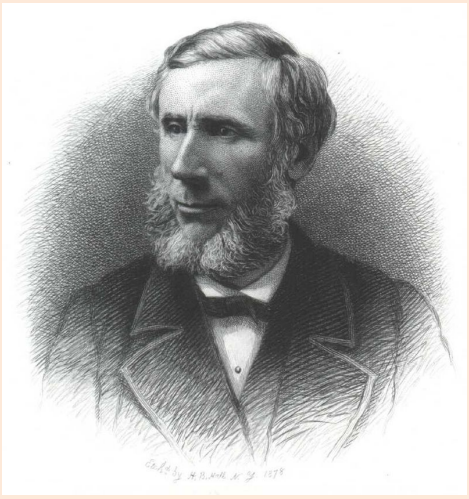
Based on the quantity of energy that a civilization can harness and use, the **Kardashev scale** is a system for evaluating that civilization's technological development. The scale was first proposed by the Soviet astronomer **Nikolai Kardashev** in 1964 and has since become a popular way of discussing the potential capabilities of advanced civilizations. **There are three main types of civilizations in the Kardashev scale:**

- **Type I:** A civilization that can harness and utilize all of the energy available on its planet. This includes energy from the sun, wind, water, and geothermal sources. A **Type I** civilization is likely to have achieved a global civilization, with a high level of technological sophistication and an efficient use of energy resources.
- **Type II:** A civilization that can harness and utilize all of the energy available from its star. This would require the construction of a **Dyson sphere** or a similar **megastructure** to completely surround the star and capture its energy output. A **Type II** civilization is likely to have colonized multiple planets in its star system and have advanced technologies such as faster-than-light travel.
- **Type III:** A civilization that can harness and utilize all of the energy available in its galaxy. This would require the construction of a **megastructure** such as a **Dyson swarm** or a similar structure to capture the energy output of billions of stars in the galaxy. A **Type III** civilization is likely to have colonized multiple galaxies and have advanced technologies such as time travel and the ability to manipulate the fabric of space-time.

There are also some proposed extensions to the **Kardashev scale**, such as **Type IV** and **Type V** civilizations, which would be able to harness and utilize energy on a cosmic scale. However, these are highly speculative and have not been observed or confirmed.

**Terraforming**

The hypothetical process of deliberately modifying the Planet's atmosphere, temperature, surface topography or ecology to be similar to those of Earth in order to make it suitable for human life.



**John Tyndall** (1820−1893) was an **Irish physicist and mountaineer** who made significant contributions to various fields, including atmospheric science, optics, and radiation. He is perhaps best known for his work on the **absorption and scattering of light** in the atmosphere, which helped to explain phenomena such as the **blue color of the sky** and the greenhouse effect. **Tyndall** was born in County **Carlow**, Ireland, and received his early education at a local school before attending Trinity College Dublin. After completing his studies, he became a professor of natural philosophy at the **Royal Institution in London**, where he conducted much of his groundbreaking research. In the 1850s and 1860s, **Tyndall** conducted a series of experiments to study the behavior of light in the atmosphere. He discovered that the blue color of the sky is caused by the scattering of sunlight by small particles in the atmosphere, a phenomenon now known as **Rayleigh scattering**. He also demonstrated that gases such as water vapor and carbon dioxide can absorb and re-emit infrared radiation, which helped to explain the **greenhouse effect**. Tyndall's work on radiation also included studies of the **absorption and transmission** of heat radiation by different materials, which led to the development of the concept of **selective absorption**. He also made significant contributions to the field of optics, including the development of a method for measuring the refractive index of gases and liquids. In addition to his scientific work, **Tyndall** was an avid mountaineer and made several pioneering ascents in the Alps. He wrote extensively about his experiences in the mountains, including his popular book **"The Glaciers of the Alps,"** which helped to popularize mountaineering as a sport. Overall, **John Tyndall** was a highly influential scientist who made significant contributions to a wide range of fields, including atmospheric science, optics, and radiation. His work helped to shape our understanding of the behavior of light and heat in the natural world, and his legacy continues to influence scientific research today.

The **critical density of the universe** is a fundamental concept in cosmology that is used to describe the overall density of matter and energy in the universe. It is defined as the amount of matter and energy that would be required for the universe to be **"flat,"** meaning that the geometry of space-time is not curved. The critical density is an important quantity because it helps us understand the ultimate fate of the universe. If the overall density of the universe is greater than the critical density, the universe will eventually collapse under the force of gravity in a **"Big Crunch."** On the other hand, if the density is less than the critical density, **the universe will continue to expand indefinitely**. The critical density can be expressed in terms of the **Hubble constant**, which describes the rate at which the universe is expanding. The Hubble constant is typically given in units of **kilometers per second per megaparsec** (km/s/Mpc), which measures the velocity at which two points in space are moving apart as a result of the universe's expansion. The **critical density** can be calculated as:

$$\rho_{crit} = \frac{3H^2}{8\pi G}$$

where $\rho_{crit}$ is the critical density, H is the Hubble constant, and G is the gravitational constant.

For H = 67.4 km/s/Mpc:

$$\rho_{crit} \approx 8.5\times10^{-27}\ kg/m^3$$

If the **critical density of the universe** were equal to the **Planck density**, it would have some significant implications for our understanding of the universe. The **Planck density** is the highest possible density that can be achieved in the universe, and it is defined as $\frac{c^5}{\hbar G^2} \approx 5.1550\times10^{96}\ kg/m^3$. If the **critical density of the universe** were equal to the **Planck density**, it would mean that the universe would be extremely small, with a radius of only a few **Planck lengths**. It would also mean that the universe would be incredibly dense, with all matter and energy compressed into a tiny volume. In this scenario, the value of the Hubble constant would be

$$\frac{c^5}{\hbar G^2} = \frac{3H^2}{8\pi G} \longrightarrow H = \frac{\sqrt{8\pi}}{\sqrt{3}\times \text{Planck time}}$$

and the universe would likely be in a state of extreme gravitational collapse, with no stars, planets, or galaxies forming. It would be a universe that is completely inhospitable to life as we know it and the laws of physics as we know them would break down. Fortunately, the **actual critical density of the universe** is much lower than the **Planck density**. This means that the universe is expanding, and has been since the Big Bang, and is not collapsing under the force of gravity. It also means that there is enough matter and energy in the universe to form stars, galaxies, and planets, and to support life.



**Georg Simon Ohm** (1789 −1854) was a German physicist and mathematician who is best known for Ohm's Law, which describes the relationship between electric current, voltage, and resistance in a circuit. **Ohm's Law** states that the current through a conductor between two points is directly proportional to the voltage across the two points, and inversely proportional to the resistance between them. **Ohm's Law** is expressed mathematically as $I = \frac{V}{R}$, where I is the current in amperes, V is the voltage in volts, and R is the resistance in ohms. This law is fundamental to the study of electrical circuits and has many practical applications in fields such as electronics and electrical engineering. **Ohm's Law** was not immediately recognized as significant when **Ohm** first published his findings in 1827. However, it was eventually widely accepted and led to the development of new technologies such as telegraphs, telephones, and electric power distribution. **Ohm's work** on electrical resistance also paved the way for later research into electrical conductivity and superconductivity. **Ohm** was a professor of mathematics and physics at the University of Munich, and he also taught at schools in Switzerland and Berlin. He published several books and papers on mathematics and physics throughout his career, and his work in these fields earned him numerous honors and awards.

If $\frac{e^2}{4\pi\varepsilon_0\hbar c}$ were greater than 0.1, stellar fusion would be impossible and no place in the cosmos would be warm enough for carbon-based life as we know it.

The ultra-high-energy cosmic ray observed in 1991 had a measured energy of about $2.5\times10^{-8}\sqrt{\frac{\hbar c^5}{G}}$

Like the formation of bubbles of steam in boiling water − Great many holograms of possible shapes and inner dimensions were created, started off in every possible way, simply because of an uncaused accident called spontaneous creation. Our universe was one among a zillion of holograms simply happened to have the right properties − with particular values of the physical constants right for stars and galaxies and planetary systems to form and for intelligent beings to emerge due to random physical processes and develop and ask questions, Who or what governs the laws and constants of physics? Are such laws the products of chance or a mere cosmic accident or have they been designed? How do the laws and constants of physics relate to the support and development of life forms? Is there any knowable existence beyond the apparently observed dimensions of our existence? However, M theory sounds so bizarre and unrealistic that there is no experiment that can credit its validity. Nature has not been quick to pay us any hints so far. That's the fact of it; grouped together everything we know about the history of the universe is a fascinating topic for study, and trying to understand the meaning of them is one of the key aspects of modern cosmology— which is rather like plumbing, in a way.

And as more space comes into existence, more of the dark energy (an invisible and unexpected cosmological force which was a vanishingly small slice of the pie 13.7 billion years ago, but today it is about three times as much as visible matter and dark matter put together and it eclipses matter and hides in empty space and works for the universe's expansion i.e., pushes the edges of the universe apart − a sort of anti-gravity) would appear. Unfortunately, no one at the present time has any understanding of where this "undetected substance" comes from or what exactly it is. Is it a pure cosmological constant (an arbitrary parameter from general relativity, has been taken to be zero for most of the twentieth century for the simple and adequate reason that this value was consistent with the data) or is it a sign of extra dimensions? What is the cause of the

dark energy? Why does it exist at all? Why is it so different from the other energies? Why is the composition of dark energy so large (of about 73% of our universe − we only make up 0.03% of the universe which include stars orbiting their galaxies much too fast to be held in orbit merely by the gravitational attraction of the observed galactic stars )?

String theory (a cutting-edge research that has integrated [Einstein's] discoveries into a quantum universe with numerous hidden dimensions coiled into the fabric of the cosmos - dimensions whose geometry may well hold the key to some of the most profound questions ever posed) gives us a clue, but there's no definitive answer. Well, all know is that it is a sort of cosmic accelerator pedal or an invisible energy what made the universe bang and if we held it in our hand; we couldn't take hold of it. In fact, it would go right through our fingers, go right through the rock beneath our feet and go all the way to the majestic swirl of the heavenly stars. It would reverse direction and come back from the stately waltz of orbiting binary stars through the intergalactic night all the way to the edge of our feet and go back and forth. How near are we to understand the dark energy? The question lingers, answer complicates and challenges everyone who yearns to resolve. And once we understand the dark energy, can we understand the birth and the death of everything in the mankind's observable universe, from a falling apple to the huge furnace (that burns billions of pounds of matter each second and reaches temperatures of tens of millions of degrees at its core) and the earth (standing at the center of the universe, surrounded by eight spheres carrying all the known heavenly bodies) is also an?

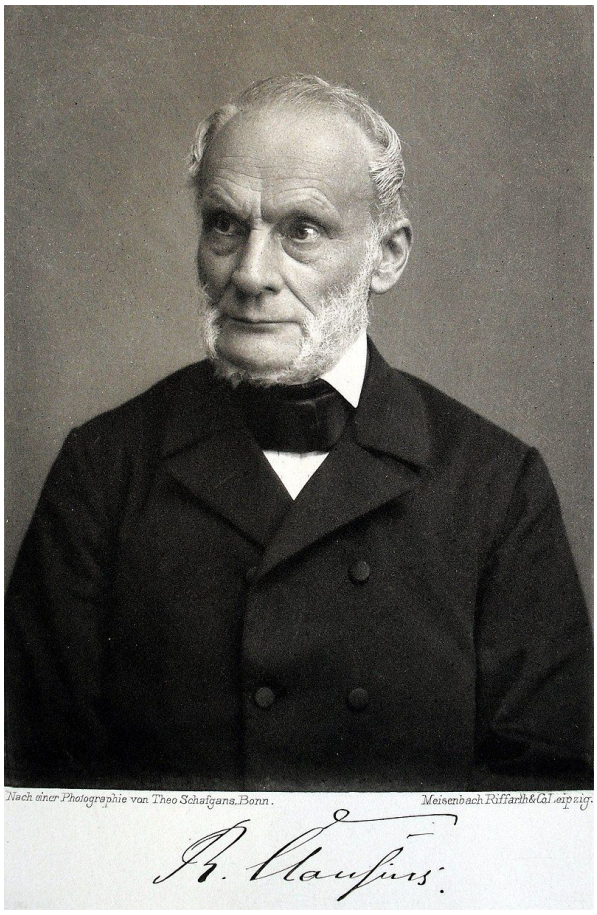
Entropy (a thermodynamic quantity −first introduced by the German physicist **Rudolf Clausius** (1822−1888) − a measure of untidiness in a system and a measure of how much information a system contains) is defined as: $S = k_B \ln \{\text{number of states}\}$ which, for N particles of the same type, will be:

$$S = k_B \ln \{(\text{no of one-particle states})^N\}$$

$$S = k_B N \ln \{\text{a not-too-big number}\}$$

$$S \approx k_B N$$

This means: the more particles, the more disorder. The entire universe is getting more disordered and chaotic with time i.e., the entropy of the universe is increasing toward greater disorder. And this observation is elevated to the status of a law, the so called Second law of thermodynamics (which was discovered by the great German physicist, **Ludwig Boltzmann** who laid down the second law of thermodynamics, committed suicide in 1906, in part because of the intense ridicule he faced while promoting the concept of atoms) i.e., the universe will tend toward a state of maximum entropy, such as a uniform gas near absolute zero (at this point, the atoms themselves almost come to a halt) and that there is nothing we have to do about it. No matter how advanced our conditions would be right for the generation of thoughts to predict things more or less, even if not in a simplest way, it can never squash the impending threat of the second law of thermodynamics (that will eventually result in the destruction of all intelligent life) nor it can bring us close to the answer of why was the entropy ever low in the first place. This makes **cosmology** (the study of the universe as a whole, including its birth and perhaps its ultimate fate) a bit more complicated than we would have hoped.




**Rudolf Clausius**

$$S = k_B \ln W$$

**For a Black hole:**

$$S = \frac{4\pi k_B G M^2}{\hbar c}$$

Black hole entropy

$$\frac{4\pi k_B G M^2}{\hbar c} = k_B \ln W$$

The number of Black hole microstates

**The higher the number of microstates, the more disordered the black hole is.**

$$W = e^{\frac{4\pi G M^2}{\hbar c}}$$

A black hole would not form with a mass below about $2.176 \times 10^{-8}$ kg (the **Planck mass** = $\sqrt{\frac{\hbar c}{G}}$).

If $M = \sqrt{\frac{\hbar c}{G}}$ :

$$W = e^{4\pi}$$

The number of microstates that correspond to the entropy of a smallest possible black hole is equal to $e^{4\pi}$

## Horizon area theorem

The **surface area of a black hole's event horizon**, which is the boundary beyond which nothing can escape the gravitational pull of the black hole, is directly proportional to the **amount of information that is stored inside the black hole**. This theorem was first proposed by physicist **Jacob Bekenstein** in the 1970s and was later developed by physicist **Stephen Hawking**, who showed that black holes can radiate energy and eventually evaporate over time, a process that is now known as **Hawking radiation**.

| **Black hole mass** **(M)** | **Black hole Evaporation time** ($t_{ev} = \frac{5120\pi G^2 M^3}{\hbar c^4}$) |
|---|---|
| $10^{11}$ kg | $\approx 2.6\times10^{9}$ years |
| 1 $M_{sun}$ | More than $10^{67}$ years ↓ **Much longer than the current age of the universe** |

# Did you know?



In his earlier work, **Professor Stephen Hawking** had suggested that information that falls into a black hole is irretrievably lost, and this led to the **paradox** that the fundamental **laws of quantum mechanics** seem to be violated. However, in his 2004 paper titled **"Information loss in black holes"**, Hawking revised his previous stance on the black hole information paradox and argued that **black holes might not be completely black**, as previously thought, but instead, they emit a faint glow of radiation that carries away information about the matter that falls into them. This radiation is now known as **Hawking radiation**, and it is caused by the quantum mechanical effects near the black hole's event horizon. According to Hawking, this radiation carries away information about the matter that was originally inside the black hole, meaning that information is not completely lost.

Let's consider an example where the **photon gas** has a total energy E and each photon has two possible energy states, corresponding to two different frequencies or wavelengths. In this case, we can calculate the number of microstates **W** as follows:

$$W = (\text{Number of microstates for each photon})^{(\text{Number of photons})}$$

Since each photon has two possible energy states:

$$W = 2^{(\text{Number of photons})}$$

Let's say that the photon gas contains N photons. Then:

$$W = 2^N$$



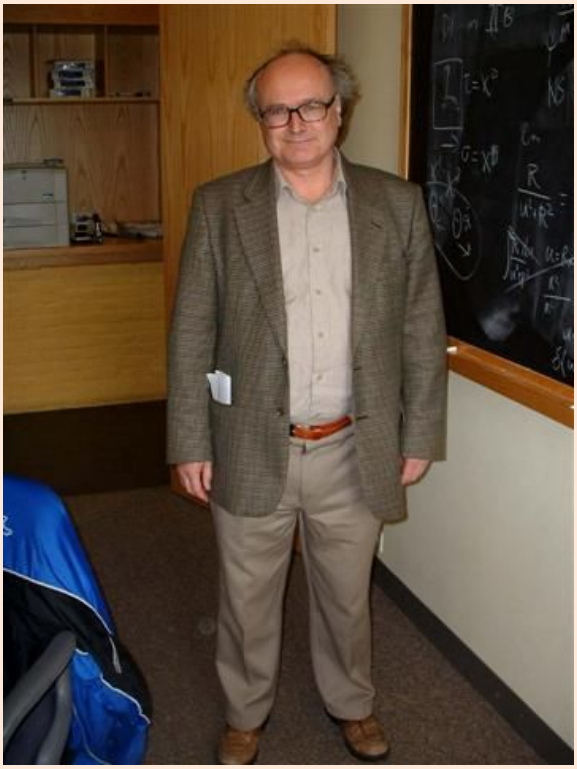
**The entropy of a photon gas:**

$$S = k_B \ln W$$

$$S = k_B \ln 2^N$$

$$S = N k_B \ln 2$$

A photon gas's entropy increases as the number of photons in the gas increases.



**Gary Gibbons** and **Stephen Hawking** showed that the **laws of thermodynamics** can be extended to **cosmological event horizons**, which are present in expanding universes. They demonstrated that these event horizons have an associated **entropy and temperature**, just like black holes. This was a significant discovery because it provided a deeper understanding of the **nature of space-time** and the relationship between **gravity and thermodynamics**. It also opened up new avenues of research in the field of cosmology, such as exploring the possible connections between the thermodynamics of cosmological horizons and the evolution of the universe as a whole. Overall, the work of **Gibbons** and **Hawking** has had a profound impact on our understanding of the fundamental principles of physics and cosmology.

$$\text{Irradiance} = \frac{\text{Radiant flux (}\mathbf{power}\text{) received by a surface}}{\text{The surface area of that surface}}$$

Suppose you have a 100 W light bulb that illuminates an area of 1 square meter. The irradiance would be:

$$\frac{100\ \text{W}}{1\ \text{m}^2} = 100\ \text{W/m}^2$$

**This means that each square meter of the illuminated area receives 100 watts of power.**

Suppose you have a solar panel with an area of 1.5 square meters and it receives 300 watts of solar radiation. The irradiance on the solar panel would be:

$$\frac{300\ \text{W}}{1.5\ \text{m}^2} = 200\ \text{W/m}^2$$

**This means that the solar panel is receiving an irradiance of 200 watts per square meter.**

| Law | Thermodynamics | Black hole mechanics |
|---|---|---|
| Zero$^{th}$ law | For a system in equilibrium, **temperature** $T \rightarrow$ constant | The **surface gravity** $\kappa$ is constant over the event horizon of a black hole. |
| First law | $dE = TdS$ **(The energy is conserved)** | $dM = \frac{\kappa\, dA}{8\pi}$ **(The mass is conserved)** |
| Second law | $dS \geq 0$ **(The entropy of a closed system never decreases)** | $dA \geq 0$ **(The area of the event horizon of a black hole never decreases)** |
| Third law | $T \rightarrow 0$ is never reached in a physical process | It is impossible to form a black hole with $\kappa \rightarrow 0$ |

$$S_{BH} = \frac{4\pi k_B G M^2}{\hbar c} = \frac{4\pi k_B M^2}{2.176 \times 10^{-8} kg}$$

For a one solar mass black hole with $\frac{2GM}{c^2} \approx 2.9$ km, $S_{BH} \approx 10^{77}$ J/K

This is an incredibly large number, which reflects the immense number of microstates that correspond to the macroscopic properties of the black hole.

$$T_{BH} = \frac{\hbar c^3}{8\pi k_B G M} \approx 6.17 \times 10^{-8} \frac{\text{Solar mass}}{M} \text{ K}$$

For a one solar mass black hole, $T_{BH} \approx \mathbf{6.17 \times 10^{-8}\,K}$

This temperature is incredibly low, and it means that the Hawking radiation from a black hole with the mass of the sun is far too weak to be detected.

For a black hole with mass M, the entropy varies as $S_{BH} \propto M^2$. The temperature typically varies as $T \propto \frac{1}{M}$, i.e. a smaller black hole will have a higher temperature than a larger black hole. For example, a black hole with a mass of 1 solar mass has a temperature of about $6.17 \times 10^{-8}$ Kelvin, while a black hole with a mass of 10 solar masses has a temperature of about $6.17 \times 10^{-9}$ Kelvin.

The amount of energy possessed by a **Schwarzschild Black Hole** is equal to its mass multiplied by the square of the speed of light: $E = Mc^2$, where: c is not just the constant namely the maximum distance a light can travel in one second in vacuum but rather a fundamental feature of the way space and time are unified to form space-time.

$$E = \frac{F_{Planck}}{2} \times R_S$$

This equation states that the energy (E) of the Black hole is proportional to the radius ($R_S$) of its event horizon, with the constant of proportionality being $\frac{F_{Planck}}{2}$, where $F_{Planck}$ is the Planck force.

$$E_S = T_{BH} \times S_{BH} = \frac{Mc^2}{2}$$

$$E_S = \frac{F_{Planck}}{4} \times R_S$$

This equation states that the entropic energy ($E_S$) of the Black hole is proportional to the radius ($R_S$) of its event horizon – with the constant of proportionality being $\frac{1}{4}^{th}$ of the Planck force.

The **Planck force** represents the maximum force that can exist in the universe according to our current understanding of physics.

The radius of a **photon orbit**, also known as the photon sphere, is the radius at which a photon can orbit a black hole in a stable circular orbit. At this radius, the gravitational attraction of the black hole is strong enough to bend the path of the photon into a circular orbit, but not strong enough to cause it to fall into the black hole. The radius of the photon orbit can be calculated using the **Schwarzschild radius**, which is a characteristic length scale associated with a non-rotating, spherically symmetric black hole. The formula for the radius of the photon orbit is:

$$R_{photon} = \frac{3GM}{c^2}$$

where $R_{photon}$ is the radius of the photon orbit, G is the gravitational constant, M is the mass of the black hole, and c is the speed of light.

Let's say we have a **black hole** with a **mass of** M = $10^6$ solar masses. We can calculate the **radius of the photon orbit** using the formula above.

$$R_{photon} = \frac{3GM}{c^2} = \frac{3 \times 6.673 \times 10^{-11} \frac{Nm^2}{kg^2} \times 10^6 \times 1.98 \times 10^{30}\ kg}{(299792458\ m/s)^2}$$

$$R_{photon} \approx 4.41028001148 \times 10^9\ m$$





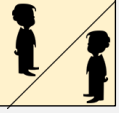
The distance from the center of a **Schwarzschild black hole** with a mass of **$10^6$ solar masses** at which a photon can orbit in a stable, circular path.

The equation: $a_{tidal} = \frac{2GMd}{R^3}$ allow us to calculate the **tidal acceleration**, $a_{tidal}$, across a body with a length of d = 2m positioned on the surface of the Earth. Given the Earth's mass, M = 5.972 × $10^{24}$ kg, and its radius, R = 6,371 km:

$$a_{tidal} = \frac{2 \times 6.673 \times 10^{-11} Nm^2/kg^2 \times 5.972 \times 10^{24}\ kg \times 2\ m}{(6{,}371\ km)^3}$$

$$a_{tidal} \approx 6.1642196 \times 10^{-6}\ m/s^2$$

Compared to the **surface gravity of the Earth** (9.8 m/s$^2$) the **tidal acceleration** across a body with a length of 2 m is quite small!



For example, **for a black hole with the mass of the Sun**, the radius of the photon orbit is approximately 5.93 kilometers (or 3.68 miles). This means that if a photon were to be emitted at this radius in the direction of the black hole, it would orbit the black hole in a stable circular orbit.

$$E = \frac{F_{Planck}}{3} \times R_{photon}$$

This equation states that the energy (E) of the Black hole is proportional to the radius ($R_{photon}$) of the photon orbit − with the constant of proportionality being $\frac{1}{3}^{rd}$ of the Planck force.

$$E_S = \frac{F_{Planck}}{6} \times R_{photon}$$

This equation states that the entropic energy ($E_S$) of the Black hole is proportional to the radius ($R_{photon}$) of the photon orbit − with the constant of proportionality being $\frac{1}{6}^{th}$ of the Planck force.

Explaining everything ... is one of the greatest challenges we have ever faced. Hence, it has been an endeavor of science to find a single theory which could explain everything, where every partial theory that we've read so far (in school) is explained as a case of the one cogent theory within some special circumstances. Despite being a mystery skeptic, the Unified Field Theory (which Albert Einstein sought [but never realized] during the last thirty years of his life and capable of describing nature's forces within a single, all-encompassing, coherent framework) presents an infinite problem. This is embarrassing. Because we now realize before we can work for the theory of everything, we have to work for the ultimate laws of nature. At the present, we're clueless as to what the ultimate laws of nature really are. Are there new laws beyond the apparently observed dimensions of our universe? Do all the fundamental laws of nature unify? At what scale? Ultimately, however, it is likely that answers to these questions in the form of unified field theory may be found over the next few years or by the end of the century we shall know can there really be a complete unified theory that would presumably solve our problems? Or are we just chasing a mirage? Is the ultimate unified theory so compelling, that it brings about its own existence? However, if we − a puny and insignificant on the scale of the cosmos − do

discover a unified field theory, it should in time be understandable in broad principle by everyone, not just a few people. Then we shall all be able to take part in the discussion of the questions of how and when did the universe begin? Was the universe created? Has this universe been here forever or did it have a beginning at the Big Bang? If the universe was not created, how did it get here? If the Big Bang is the reason there is something rather than nothing, and then before the Big Bang there was NOTHING and then suddenly we got A HUGE AMOUNT OF ENERGY where did it come from? What powered the Big Bang? What is the fate of the Universe? Is the universe heading towards a Big Freeze (the end of the universe when it reaches near absolute zero), a Big Rip, a Big Crunch (the final collapse of the universe), or a Big Bounce? Or is it part of an infinitely recurring cyclic model? Is inflation a law of Nature? Why the universe started off very hot and cooled as it expanded? Is the Standard Big Bang Model right? Or is it the satisfactory explanation of the evidence which we have and therefore merits our provisional acceptance? Is our universe finite or infinite in size and content? What lies beyond the existing space and time? What was before the event of creation? Why is the universe so uniform on a large scale (even though uncertainty principle − which fundamentally differentiates quantum from classic reasoning− discovered by the German physicist Werner Heisenberg in 1927 − implies that the universe cannot be completely uniform because there are some uncertainties or fluctuations in the positions and velocities of the particles)? Why does it look the same at all points of space and in all directions? In particular, why is the temperature of the cosmic microwave back- ground radiation so nearly the same when we look in different directions? Why are the galaxies distributed in clumps and filaments? When were the first stars formed, and what were they like? Or if string theory (which is part of a grander synthesis: M-theory and have captured the hearts and minds of much of the theoretical physics community while being apparently disconnected from any realistic chance of definitive experimental proof) is right i.e., every particle is a tiny one dimensional vibrating string of Planck length (the smallest possible length i.e., Planck time multiplied by the speed of light)?

Why most of the matter in the Universe is dark? Is anthropic principle a natural coincidence? If we find the answers to them, it would be the ultimate triumph of human reason i.e., we might hold the key to address the eternal conundrum of some of the most difficult issues in modern

physics. Yet those difficult issues are also the most exciting, for those who address big, basic questions: What do we really know about the universe? How do we know it? Where did the universe come from, and where is it going? It would bring to an end a long and glorious lesson in the history of mankind's intellectual struggle to understand the universe. For then we would know whether the laws of physics started off the universe in such an incomprehensible way or not. Chances are that these questions will be answered long after we're gone, but there is hope that the beginnings of those answers may come within the next few years, as some aspects of bold scientific theory that attempts to reconcile all the physical properties of our universe into a single unified and coherent mathematical framework begin to enter the realm of theoretical and experimental formulation.

Up until recently, a multitude of revolutions in various domains, from literature to experimental science, has prevailed over established ideas of modern age in a way never seen before. But we do not know about what is the exact mechanism by which an implosion of a dying star becomes a specific kind of explosion called a supernova. All that we know is that: When a massive star runs out of nuclear fuel, the gravitational contraction continues increasing the density of matter. And since the internal pressure is proportional to the density of matter, therefore the internal pressure will continually increase with the density of matter. And at a certain point of contraction, internal pressure will be very much greater than gravitational binding pressure and will be sufficiently high enough to cause the star to explode, spraying the manufactured elements into space that would flung back into the gas in the galaxy and would provide some of the raw material for the next generation of stars and bodies that now orbit the sun as planets like the Earth. The total energy released would outshine all the other stars in the galaxy, approaching the luminosity of a whole galaxy (will nearly be the order of 10 to the power of 42 Joules). In the aftermath of the supernova, we find a totally dead star, a neutron star – a cold star, supported by the exclusion principle repulsion between neutrons – about the size of Manhattan (i.e., ten to 50 times the size of our sun).

Why are there atoms, molecules, solar systems, and galaxies? What powered them into existence? How accurate are the physical laws and equations, which control them? Why do the

Fundamental Constants of Nature have the precise values they do? The answers have always seemed well beyond the reach of Dr. Science since the dawn of humanity − until now (some would claim the answer to these questions is that there is a transcendent God (a cosmic craftsman – a transcendent being than which no being could be more virtuous) who chose to create the universe that way according to some perfect mathematical principle. Then the question merely reflects to that of who or what created the God). But the questions are still the picture in the mind of many scientists today who do not spend most of their time worrying about these questions, but almost worry about them some of the time. All that science could say is that: The universe is as it is now. But it could not explain why it was, as it was, just after the Big Bang. This is a disaster for science. It would mean that science alone, could not predict how the universe began. Every attempt is made to set up the connection between theoretical predictions and experimental results but some of the experimental results throw cold water on the theoretical predictions.

Back in 1700s, people thought the stars of our galaxy structured the universe, that the galaxy was nearly static, and that the universe was essentially unexpanding with neither a beginning nor an end to time. A situation marked by difficulty with the idea of a static and unchanging universe, was that according to the Newtonian theory of gravitation, each star in the universe supposed to be pulled towards every other star with a force that was weaker the less massive the stars and farther they were to each other. It was this force caused all the stars fall together at some point. So how could they remain static? Wouldn't they all collapse in on themselves? A balance of the predominant attractive effect of the stars in the universe was required to keep them at a constant distance from each other. Einstein was aware of this problem. He introduced a term so-called cosmological constant in order to hold a static universe in which gravity is a predominant attractive force. This had an effect of a repulsive force, which could balance the predominant attractive force. In this way it was possible to allow a static cosmic solution. Enter the American astronomer Edwin Hubble. In 1920s he began to make observations with the hundred inch telescope on Mount Wilson and through detailed measurements of the spectra of stars he found something most peculiar: stars moving away from each other had their spectra shifted toward the red end of the spectrum in proportion to the distance between them (This was a Doppler effect of light: Waves of any sort − sound waves, light waves, water waves − emitted at some frequency

by a moving object are perceived at a different frequency by a stationary observer. The resulting shift in the spectrum will be towards its red part when the source is moving away and towards the blue part when the source is getting closer). And he also observed that stars were not uniformly distributed throughout space, but were gathered together in vast collections called galaxies and nearly all the galaxies were moving away from us with recessional velocities that were roughly dependent on their distance from us. He reinforced his argument with the formulation of his well- known Hubble's law. The observational discovery of the stretching of the space carrying galaxies with it completely shattered the previous image of a static and unchanging cosmos (i.e., the motivation for adding a term to the equations disappeared, and Einstein rejected the cosmological constant a greatest mistake).

We story telling animals (who TALK ABOUT THE nature of the universe and discuss such questions as whether it has a beginning or an end) often claim that we know so much more about the universe. But we must beware of overconfidence. We have had false dawns before. At the beginning of this century, for example, it was thought that earth was a perfect sphere, but latter experimental observation of variation of value of "$g = \frac{GM}{R^2}$" over the surface of earth confirmed that earth is not a perfect sphere. Today there is almost universal agreement that space itself is stretching, carrying galaxies with it, though we are experimentally trying to answer whether cosmic [expansion will] continue forever or slow to a halt, reverse itself [and] lead to a cosmic implosion. However, personally, we're sure that the accelerated expansion began with a state of infinite compression and primeval explosion called the hot Big Bang. But will it expand forever or there is a limit beyond which the average matter density exceeds a hundredth of a billionth of a billionth of a billionth ($10^{-29}$) of a gram per cubic centimeter so- called critical density (the density of the universe where the expansion of the universe is poised between eternal expansion and recollapse)... then a large enough gravitational force will permeate the cosmos to halt and reverse the expansion or the expansion and contraction are evenly balanced? We're less sure about that because events cannot be predicted with complete accuracy but that there is always a degree of uncertainty.

For an **electron**, the charge is $-1.602 \times 10^{-19}$ Coulombs and the mass is $9.109 \times 10^{-31}$ kg. Therefore, the charge to mass ratio of an electron is:

$$\frac{e}{m_e} = \frac{-1.602 \times 10^{-19}\ C}{9.109 \times 10^{-31}\ kg} \approx -1.758 \times 10^{11}\ C/kg$$

For a **proton**, the charge is $+1.602 \times 10^{-19}$ Coulombs and the mass is $1.672 \times 10^{-27}$ kg. Therefore, the charge to mass ratio of a proton is:

$$\frac{e}{m_p} = \frac{+1.602 \times 10^{-19}\ C}{1.672 \times 10^{-27}\ kg} \approx 9.581 \times 10^{7}\ C/kg$$

The charge to mass ratio of an electron is much larger in magnitude compared to that of a proton **indicating that the electron is much more affected by electric and magnetic fields compared to a proton.**

## Why Quarks feel the strong force, leptons do not?

The reason why **quarks** feel the strong force while **leptons** do not is due to their different properties. **Quarks** carry a property called "color charge," which comes in three types: red, green, and blue. The strong force interacts with quarks through their color charge, causing them to attract and repel each other. **Leptons**, on the other hand, do not carry any color charge and therefore do not interact with the strong force.

## Particle physics experiment

- Prepare the interacting particles
- Cause the particles to come into contact
- Identify and measure the products

At scales smaller than the **Planck length**, it is believed that the structure of space-time itself becomes uncertain and cannot be meaningfully described using our current theories.

$$\frac{\text{Planck temperature}}{\text{CMB temperature}} = \frac{1.416 \times 10^{32}\ \text{K}}{2.73\ \text{K}} \approx 5.18 \times 10^{31}$$

The **Planck temperature** is approximately about $5.18 \times 10^{31}$ times higher than the **CMB temperature**. The **Planck temperature** is the highest temperature scale in physics and is thought to be the maximum temperature that can be achieved in the universe. The **CMB temperature**, on the other hand, is a remnant of the **Big Bang** and is considered to be the coolest temperature that can exist in the universe.

$$\frac{\text{Surface temperature of the sun}}{\text{CMB temperature}} = \frac{5772\ \text{K}}{2.73\ \text{K}} \approx 2114.2$$

This means that the surface temperature of the Sun is approximately about 2114 times hotter than the cosmic microwave background temperature.

## Is it appropriate to discuss the "universe" prior to the Big Bang?

The term **"universe"** refers to everything that exists, including all matter, energy, and space. The concept of the universe before the Big Bang is a subject of ongoing scientific inquiry and philosophical debate. According to current scientific theories, the **Big Bang** marks the beginning of the observable universe as we know it. However, some theoretical models suggest that the universe could have existed in a different form or state before the **Big Bang**, but it would have been unobservable to us due to the extreme conditions of that era. Therefore, it is sensible to talk about the universe before the **Big Bang** in a speculative sense, but the lack of empirical evidence makes it difficult to make definitive claims or draw concrete conclusions about the pre-Big Bang universe.

## Does the 'moment' of creation fall under the purview of the laws of quantum theory?

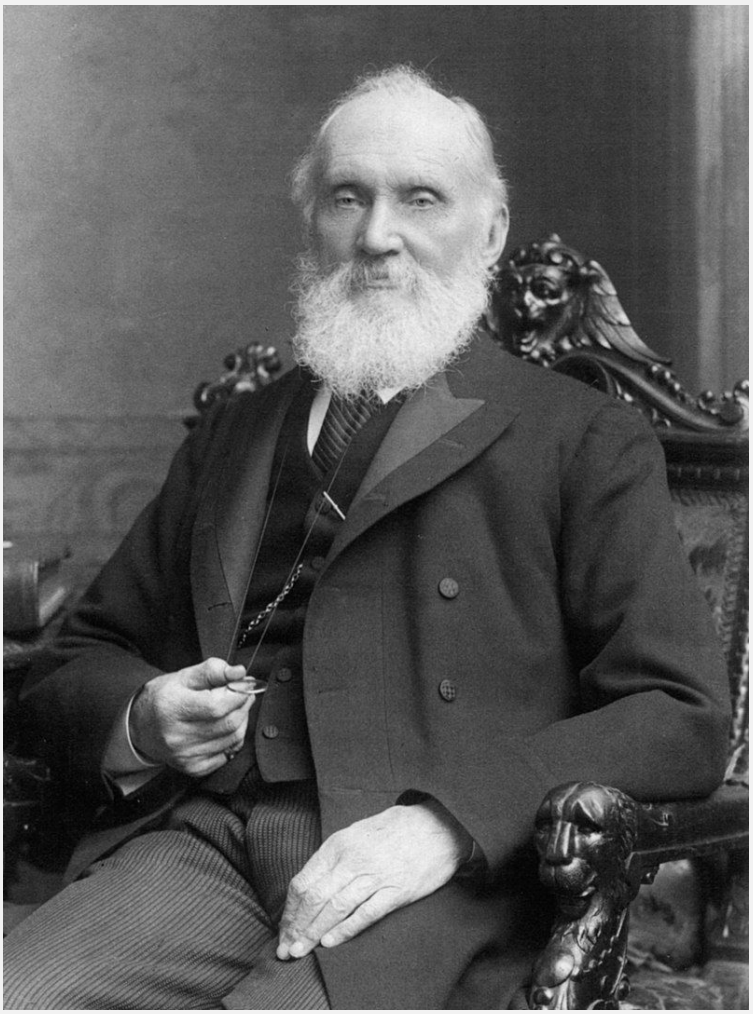
The **laws of quantum theory** are believed to operate at all times, including during the moment of creation or the Big Bang. However, our understanding of the universe at that early stage is limited because our current theories, including quantum theory, break down under the extreme conditions that existed at that time. The **singularity** at the moment of the **Big Bang** represents a state of infinite density and temperature where the laws of physics as we know them cease to be valid. In this sense, we cannot currently apply quantum theory to describe the **Big Bang** itself, but we can use it to understand the evolution of the universe after that initial state. Nevertheless, physicists are working on developing new theories that can better describe the conditions of the early universe, including the **moment of creation**. These theories aim to unify **quantum mechanics** and **general relativity**, the two pillars of modern physics, and could help us gain a better understanding of the very beginning of the universe.

The **tidal acceleration** across a body with a length of 2m positioned on the surface of the stellar-mass **black hole** of one solar mass ($1.98910 \times 10^{30}$ kg) and a radius of 2.9 km is:

$$a_{tidal} = \frac{2 \times 6.673 \times 10^{-11} \mathrm{Nm^2/kg^2} \times 1.98910 \times 10^{30}\ \mathrm{kg} \times 2\ \mathrm{m}}{(2.9\ \mathrm{km})^3}$$

$$a_{tidal} \approx 2.17692636844 \times 10^{10}\ \mathrm{m/s^2}$$

The **tidal acceleration** across a body with a length of 2 m is quite large and a body would be pulled apart and **'spaghettified'**



The idea of universal heat death was indeed proposed by **Lord Kelvin** (William Thomson) in 1852.

**Distance close to a black hole**

$d < \frac{3GM}{c^2}$ , there are no stable orbits − all matter and radiation gets sucked in.

At $d = \frac{3GM}{c^2}$, photons would orbit in a circle!

**Warm inflation** is a theoretical model in cosmology that combines elements of both **inflationary cosmology** and **thermal field theory**. In **warm inflation**, the universe undergoes a period of accelerated expansion, similar to the inflationary period in **standard inflationary cosmology**, but instead of being driven by a scalar field with a potential energy; the expansion is driven by the **thermal energy of the universe**. In **warm inflation**, the universe is not completely empty during the inflationary period, as it is in **standard inflationary cosmology**. Instead, there is a thermal bath of particles that interacts with the **inflation field**, providing the necessary energy to drive the accelerated expansion. The interactions between the **inflation field** and the thermal bath also create a dissipative force, which slows down the motion of the **inflation field**, leading to a more gradual end to the inflationary period. One of the advantages of **warm inflation** over **standard inflationary cosmology** is that it can generate a nearly scale-invariant spectrum of density perturbations, which is consistent with observations of the **cosmic microwave background radiation. Warm inflation** can also naturally generate the right amount of gravitational waves, which could potentially be detected by future experiments. However, there are still some challenges to be addressed in the **warm inflation model**, including the need for a mechanism to generate the initial thermal bath and the problem of reheating the universe after the inflationary period ends.

**INFLATION** $\rightarrow \frac{da}{dt} > 0$

**INFLATION** $\rightarrow (\rho + 3P) < 0$ **or** $P < -\frac{\rho}{3}$

- a is the scale factor of the universe.
- P is the overall pressure of the universe.
- ρ is the density of the universe.



**Planck mass** = $\sqrt{\frac{\hbar c}{G}} \approx 2.176 \times 10^{-8}\,\text{kg}$

This value represents the scale at which **quantum mechanics** and **general relativity** become equally important and is considered to be the natural unit of mass in the Planck system of units.

$$\frac{\text{Planck mass}}{\text{electron mass}} = \frac{2.176 \times 10^{-8}\,\text{kg}}{9.109 \times 10^{-31}\,\text{kg}} \approx 2.38 \times 10^{22}$$

$2.38 \times 10^{22}$ electron masses make up one Planck mass

$$\frac{\text{Planck mass}}{\text{proton mass}} = \frac{2.176 \times 10^{-8}\,\text{kg}}{1.672 \times 10^{-27}\,\text{kg}} \approx 1.30 \times 10^{19}$$

$1.30 \times 10^{19}$ proton masses make up one Planck mass

## The surface gravity of the Sun can be calculated using the formula:

$$g = \frac{GM_{Sun}}{R_{Sun}^2} = \frac{6.67384 \times 10^{-11}\,\text{Nm}^2/\text{kg}^2 \times 1.98910 \times 10^{30}\,\text{kg}}{(6.9550 \times 10^{8}\,\text{m})^2} \approx 274\ \text{m/s}^2$$

≈ 109.2 times the radius of the Earth

The surface gravity of the Sun is approximately 274 m/s$^2$. This is much stronger than the surface gravity of the Earth, which is approximately 9.8 m/s$^2$. The high surface gravity of the Sun is due to its large mass (which is roughly about 330,000 times the mass of the Earth).

**The Schwarzschild radius of the Sun is given by:**

$$\mathbf{R_S} = \frac{2GM_{Sun}}{c^2} = \frac{6.67384 \times 10^{-11}\ \mathrm{Nm^2/kg^2} \times 1.98910 \times 10^{30}\ \mathrm{kg}}{(2.997\,924\,58 \times 10^{8}\ \mathrm{m/s})^2} \approx 2.9\ \mathrm{km}$$

This means that if the Sun were to collapse to a radius of less than 2.9 kilometers, its escape velocity would exceed the speed of light, and it would be a **black hole**. The Sun will not become a **black hole** because it does not have enough mass to collapse under its own gravity to a size smaller than its **Schwarzschild radius**. In order for a star to become a black hole, it must have a mass greater than about three times that of the Sun. When a massive star exhausts its nuclear fuel, it undergoes a gravitational collapse, which causes its core to shrink and become denser. If the core is massive enough, it will collapse to a point of zero volume known as a singularity, creating a black hole. However, the Sun does not have enough mass to undergo this process. After it exhausts its nuclear fuel in about 5 billion years, it will expand into a red giant and then shed its outer layers to become a white dwarf, a dense stellar remnant about the size of the Earth but with a mass about half that of the Sun.

**Escape velocity** is the minimum velocity required by a particle to break free from the gravitational pull of a celestial body, such as a planet or a moon, and move into space. The formula to calculate the **escape velocity** is given by: $v_{escape} = \sqrt{\frac{GM}{R}}$

As the mass and radius of the celestial object increase, the escape velocity of the particle increases.

where v is the escape velocity, G is the gravitational constant, M is the mass of the celestial body, and r is the distance from the center of the celestial body to the particle's starting point. The escape velocity depends on the mass and size of the celestial body. For example, the **escape velocity** of the particle from Earth is about 11.2 km/s, while the **escape velocity** of the particle from the Moon is much lower, about 2.38 km/s, due to the Moon's lower mass and smaller size. For a thermal particle, its velocity is determined by its temperature and mass: $v = \sqrt{\frac{3k_BT}{m}}$

The minimum velocity required by a thermal particle to break free from the gravitational pull of a celestial body and move into space is: $v_{escape} = v$ i.e., $v_{escape} = \sqrt{\frac{3k_BT}{m}}$

The escape velocity of thermal particles is determined by the temperature and mass of the particle

The picture of standard model of the Forces of Nature (a sensible and successive quantum-mechanical description developed by 1970s physicists) is in good agreement with all the observational evidence that we have today and remains consistent with all the measured properties of matter made in our most sophisticated laboratories on Earth and observed in space with our most powerful telescopes. Nevertheless, it leaves a number of important questions unanswered like the unanswered questions given in The Hitchhiker's Guide to the Galaxy (by Douglas Adams): Why are the strengths of the fundamental forces (electromagnetism, weak and strong forces, and gravity) are as they are? Why do the force particles have the precise masses they do? Do these forces really become unified at sufficiently high energy? If so how? Are there unobserved fundamental forces that explain other unsolved problems in physics? Why is gravity so weak? May because of hidden extra dimensions? Very likely, we are missing something important that may seem as obvious to us as the earth orbiting the sun – or perhaps as ridiculous as a tower of tortoises. Only time (whatever that may be) will tell.

The theory of evolution (which predicts: that the use of antiviral or antibacterial agents would result in the emergence of resistant strains. This principle is, of course, a mainstay of contemporary medicine and asserts that the natural selection is a choice of stable forms and a rejection of unstable ones. And the variation within a species occurs randomly, and that the survival or extinction of each organism depends upon its ability (an internal force or tendency) to adapt to the environment) lined up pictures of apes and humans and claimed that humans evolved from apes (i.e., the chimpanzee and the human share about 99.5 per cent of their evolutionary history). This spilled out onto the corridors of the academy and absolutely rocked Victorian England to the extent that people just barely raised their voice contradicting the biblical account of creation in the lecture hall rips of the architrave. And despite more than a century of digging straight down and passing through the fossil layers, the fossil record remains maddeningly sparse and provides us with no evidence that show evolutionary transition development of one species into another species. However, we are convinced that the theory of evolution, especially the extent to which it’s been believed with blind faith, which may turn to be one of the great fairy tales for adults in the history books of the future. Like raisins in expanding dough, galaxies that are further apart are increasing their separation more than nearer ones. And

as a result, the light emitted from distant galaxies and stars is shifted towards the red end of the spectrum. Observations of galaxies indicate that the universe is expanding: the distance D between almost any pair of galaxies is increasing at a rate V = HD − beautifully explained by the Hubble's law (the law that agrees with Einstein's theory of an expanding universe). However, controversy still remains on the validity of this law. Andromeda, for example, for which the Hubble relation does not apply. And quantum theory (The revolutionary theory of the last century clashed with everyday experience which has proved enormously successful, passing with flying colors the many stringent laboratory tests to which it has been subjected for almost a hundred years) predicts that entire space is not continuous and infinite but rather quantized and measured in units of quantity called Planck length ($10^{-33}$ cm – the length scale found at the big bang in which the gravitational force was as strong as the other forces and at this scale, space-time was "foamy," with tiny bubbles and wormholes appearing and disappearing into the vacuum). However, at the present there is no conclusive evidence in favor of quantization of space and time and moreover nobody knows why no spatial or time interval shorter than the Planck values exists?

For length: Planck length (a hundred billion billion times [$10^{20}$] smaller than an atomic nucleus and $10^{-20}$ times the diameter of a proton) = $\sqrt{\frac{G\hbar}{c^3}} \approx 1.6 \times 10^{-33}$ centimeter.

For time: Planck time (represents a rough time scale at which quantum gravitational effects are likely to become important) = $\sqrt{\frac{G\hbar}{c^5}} \approx 5.3 \times 10^{-44}$ seconds.

On the other hand, there is no evidence against what the quantum model inform us about the true nature of reality. But in order to unify Albert Einstein's general relativity (a theoretical framework for understanding the universe on the largest of scales: the immense expanse of the universe itself and it breaks down at times less than the Planck time and at distances smaller than the Planck length, predicts the existence of wormhole − a passageway between two universes – gives us a better way of grasping reality than Newtonian mechanics, because it tells us that there can be black holes, because it tells us there's a Big Bang) with the quantum physics that describe fundamental particles and forces, it is necessary to quantize space and perhaps time as well. And

for a universe to be created out of nothing, the positive energy of motion should exactly cancel out the negative energy of gravitational attraction i.e., the net energy of the universe should be = zero. And if that's the case, the spatial curvature of the universe, $\Omega_k$, should be = 0.0000 (i.e., perfect flatness). But the Wilkinson Microwave Anisotropy Probe (WMAP) satellite has established the spatial curvature of the universe, $\Omega_k$, to be between − 0.0174 and + 0.0051. Then, how can it cost nothing to create a universe, how can a whole universe be created from nothing? On the other hand, there is a claim that the sum of the energy of matter and of the gravitational energy is equal to zero and hence there is a possibility of a universe appearing from nothing and thus the universe can double the amount of positive matter energy and also double the negative gravitational energy without violation of the conservation of energy. However, energy of matter + gravitational energy is = zero is only a claim based on Big Bang implications. No human being can possibly know the precise energy content of the entire universe. In order to verify the claim that the total energy content of the universe is exactly zero, one would have to account for all the forms of energy of matter in the universe, add them together with gravitational energy, and then verify that the sum really is exactly zero. But the attempt to verify that the sum really is exactly zero is not an easy task. We need precision experiments to know for sure.

Gazing at the at the blazing celestial beauty of the night sky and asking a multitude of questions that have puzzled and intrigued humanity since our beginning − WE'VE DISCOVERED a lot about our celestial home; however, we still stand at a critical cross road of knowledge where the choice is between spirituality and science to accomplish the hidden truth behind the early evolution of the universe. In order to throw light on a multitude of questions that has so long occupied the mind of scientists and the people who have argued over the years about the nature of reality and whose business it is to ask why, the philosophers: Where did we and the universe come from? Where are we and the universe going? What makes us and the universe exists? Why we born? Why we die? Whether or not the universe had a beginning? If the universe had a beginning, why did it wait an infinite time before it began? What was before the beginning? Is our universe tunneled through the chaos at the Planck time from a prior universe that existed for all previous time? We must either build a sound, balanced, effective and extreme imaginative knowledge beyond our limit. Many theories were put forth by the scientists to look into the early

evolution of the universe but none of them turned up so far. And if, like me, you have wondered looking at the star, and tried to make sense of what makes it shine the way it is. Did it shine forever or was there a limit beyond which it cannot or may not shine? And, where did the matter that created it all come from? Did the matter have a beginning in time? Or had the matter existed forever and didn't have a beginning? In other words, what cause made the matter exist? And, what made that cause exist? Some would claim the answer to this question is that matter could have popped into existence 13.9 billion years ago as a result of just the eminent physical laws and constants being there. Any "meta" or "hyper" laws of physics that would allow (even in postulate) a matter to pop into existence are completely outside our experience. The eminent laws of physics, as we know them, simply are not applicable here. Invoking the laws of physics doesn't quite do the trick. And the laws of physics are simply the human-invented ingredients of models that we introduce to describe observations. They are all fictitious, as far as we find a reference frame in which they are observed. The question of matter genesis is clear, and deceptively simple. It is as old as the question of what was going on before the Big Bang. Usually, we tell the story of the matter by starting at the Big Bang and then talking about what happened after. The answer has always seemed well beyond the reach of science. Until now.

Over the decades, there have been several heroic attempts to explain the origin of matter, all of them proven wrong. One was the so-called Steady State theory. The idea was that, as the galaxies moved apart from each other; new galaxies would form in the spaces in between, from matter that was spontaneously being created. The matter density of the universe would continue to exist, forever, in more or less the same state as it is today. In a sense disagreement was a credit to the model, every attempt was made to set up the connection between theoretical predictions and experimental results but the Steady State theory was disproved even with limited observational evidence. The theory therefore was abandoned and the idea of spontaneous creation of matter was doomed to fade away into mere shadows. As crazy as it might seem, the matter may have come out of nothing! The meaning of nothing is somewhat ambiguous here. It might be the pre-existing space and time, or it could be nothing at all. After all, no one was around when the matter began, so who can say what really happened? The best that we can do is

work out the most vain imaginative and foolish theories, backed up by numerous lines of scientific observations of the universe.

Cats are alive and dead at the same time. But some of the most incredible mysteries of the quantum realm (a jitter in the amorphous haze of the subatomic world) get far less attention than Schrödinger's famous cat. Due to the fuzziness of quantum theory (that implies: the cosmos does not have just a single existence or history), and specifically Heisenberg's uncertainty principle (which fundamentally differentiates quantum from classic reasoning − discovered by the German physicist Werner Heisenberg in 1927), one can think of the vacuum fluctuations as virtual matter –antimatter pairs that appear together at some time, move apart, then come together and annihilate one another and revert back to energy. Spontaneous births and deaths of roiling frenzy of particles so called virtual matter –antimatter pairs momentarily occurring everywhere, all the time – is the evidence that mass and energy are interconvertible; they are two forms of the same thing. If one argue that matter was a result of such a fluctuation. So then the next question is what cause provided enough energy to make the virtual matter – antimatter pairs materialize in real space. And if we assume some unknown cause has teared the pair apart and boosted the separated virtual matter –antimatter into the materialized state. The question then is what created that cause. In other words, what factor created that cause? And what created that factor. Or perhaps, the cause, or the factor that created it, existed forever, and didn't need to be created. The argument leads to a never-ending chain that always leaves us short of the ultimate answer. Unfortunately, Dr. Science cannot answer these questions. So, the problem remains. However, quantum origin and separation of the matter still delights theoretical physicists but boggles the mind of mere mortals, is the subject of my thought; have the quantum laws found a genuinely convincing way to explain matter existence apart from divine intervention? If we find the answer to that, it would be the ultimate triumph of human reason – for then we would know the ultimate Cause of the Matter. Over the decades, we're trying to understand how the matter began and we're also trying to understand all the other things that go along with it. This is very much the beginning of the story and that story could go in, but I think there could be surprises that no one has even thought of. Something eternal can neither be created nor destroyed. The first law of thermodynamics (a version of the law of conservation of energy, adapted for thermodynamic

systems) asserts that matter or energy can neither be created nor destroyed; it can be converted from one form to another.

The overwhelming experience of experimental science (science based on experimental research that plays the role of testing hypothesis, typically in controlled laboratory settings) confirms this first law to be a fact. But if the matter prevails in the boundary of understanding in that it neither started nor it ends: it would simply be. What place then for an evidence exposing that we live in a finite expanding universe which has not existed forever, and that all matter was once squeezed into an infinitesimally small volume, which erupted in a cataclysmic explosion which has become known as the Big Bang. However, what we believe about the origin of the matter is not only sketchy, but uncertain and based purely on human perception. There is no reliable and genuine evidence to testify about how the matter began and what may have existed before the beginning of the matter. The laws of physics tell us that the matter had a beginning, but they don't answer how it had begun. Mystery is running the universe in a hidden hole and corner, but one day it may wind up the clock work with might and main. The physical science can explain the things after big bang but fails to explain the things before big bang. We know that matter can be created out of energy, and energy can be created out of matter. This doesn't resolve the dilemma because we must also know where the original energy came from.

The electrostatic and gravitational forces according to Coulomb's and Newton's laws are both inverse square forces, so if one takes the ratio of the forces, the distances cancel. For the electron and proton, the ratio of the forces is given by the equation: $\frac{F_E}{F_G} = \frac{e^2}{4\pi\varepsilon_0 G m_p m_e}$, where e is the charge = $1.602 \times 10^{-19}$ Coulombs, G is the gravitational constant, $\varepsilon_0$ is the absolute permittivity of free space = $8.8 \times 10^{-12} \frac{F}{m}$, $m_p$ is the mass of the proton = $1.672 \times 10^{-27}$ kg and $m_e$ is the mass of the electron = $9.1 \times 10^{-31}$ kg. Plugging the values we get: $\frac{F_E}{F_G} = 10^{39}$ which means: $F_E$ is > $F_G$. So, it was argued by a German mathematician, theoretical physicist and

philosopher (some say it was Hermann Weyl), if the gravitational force between the proton and electron were not much smaller than the electrostatic force between them, then the hydrogen atom would have collapsed to neutron long before there was a chance for stars to form and life to evolve. $F_E > F_G$ must have been numerically fine-tuned for the existence of life. Taking $\frac{F_E}{F_G} = 10^{39}$ as an example in most physics literature we will find that gravity is the weakest of all forces, many orders of magnitude weaker than electromagnetism. But this does not make sense any way and it is not true always and in all cases. Note that the ratio $\frac{F_E}{F_G}$ is not a universal constant; it's a number that depends on the particles we use in the calculation. For example: For two particles each of Planck mass (mass on the order of 10 billion billion times that of a proton) and Planck charge the ratio of the forces is 1 i.e., $\frac{F_E}{F_G} = 1$. Moreover, when the relativistic variation of electron mass with velocity is taken into account then the ratio $\frac{F_E}{F_G}$ becomes velocity dependent.

Does our universe exist inside a black hole of another universe? The question lingers, unanswered until now. Even though the existence of alternative histories with black holes, suggests this might be possible i.e., our universe lies inside a black hole of another universe, we cannot prove or disprove this conjecture any way. Meaning that the event horizon of a black hole is boundary at which nothing inside can escape and then how might one can cross its event boundary and testify whether or not our universe exist inside a black hole of another universe. Thus we cannot answer the central question in cosmology: Does our universe exist inside a black hole of another universe? However, the fact that we are simply an advanced breed of talking monkeys surviving on a sumptuous planet, have been reckoning at least from last hundred years − turning unproved belief into unswerving existence through the power of perception and spending our brief time in the sun working at understanding the deepest mysteries of nature by doing repeated calculations and getting some answer that seem very likely makes us feel something very special-- a bit premature to buy tickets to the nearest galaxy to visit the next goldilocks planet or hunt dinosaurs.

The physicist has been spending a month, as he or she does each year, sequestered with colleagues, such as fellow theoretical physicists, to discuss many great mysteries of the cosmos. But despite its simple approximation as a force, and its beautifully subtle description as a property of space-time which in turn can be summarized by Einstein's famous equation, which essentially states: Matter-energy → curvature of space- time, we've come to realize over the past century that we still don't know what gravity actually is. It has been a closed book ever since the grand evolution of human understanding and all physicists hang this book up on their wall and distress about it. Unhesitatingly you would yearn to know where this book comes from: is it related to metaphysical science or perhaps to the greatest blast puzzles of physics still to be discovered, like cosmic string and magnetic monopoles? Nobody knows and for the moment, nature has not said yes in any sense. It's one of the 10,000 bits puzzling cosmic story with a cracking title. You might say the laws of physics designed that book, and we don't know how they designed that book. The elevated design of this book, an extract of which appears in the cosmic art gallery, sets out to the belief that it must have designed as it could not have created out of chaos. In some sense, the origin of the cosmic problem today remains what it was in the time of Newton (who not only put forward a theory of how bodies move in space and time, but he also developed the complicated mathematics needed to analyze those motions) – one of the greatest challenges of 21st Century science certainly keep many an aficionado going. Yet, we toasting each other with champagne glasses in laboratories around the world—have made a bold but brilliant move. In less than a hundred years, we have found a new way to wonder what gravity is. The usual approach of science of constructing a set of rules and equations cannot answer the question of why if you could turn off gravity, space and time would also vanish. In short, we don't have an answer; we now have a whisper of the grandeur of the problem. We don't know exactly how it is intimately related to space and time. It's a mystery that we're going to chip at from quantum theory (the theory developed from Planck's quantum principle and Heisenberg's uncertainty principle which deals with phenomena on extremely small scales, such as a millionth of a millionth of an inch). However, when we try to apply quantum theory to gravity, things become more complicated and confusing.

✓ **The electrostatic and gravitational forces acting between the 2 electrons are:**

$$F_{electrostatic} = \frac{e^2}{4\pi\varepsilon_0 r^2} = (8.99 \times 10^9\ Nm^2\ C^{-2}) \times \frac{(1.602 \times 10^{-19} C)^2}{r^2}$$

$$F_{gravitation} = \frac{Gm_e^2}{r^2} = (6.673 \times 10^{-11}\ Nm^2 kg^{-2}) \times \frac{(9.109 \times 10^{-31} kg)^2}{r^2}$$

$$\frac{F_{electrostatic}}{F_{gravitation}} \approx 4.1 \times 10^{42}$$

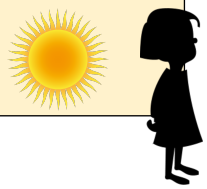
✓ **The electrostatic and gravitational forces acting between the 2 protons are:**

$$F_{electrostatic} = \frac{e^2}{4\pi\varepsilon_0 r^2} = (8.99 \times 10^9\ Nm^2\ C^{-2}) \times \frac{(1.602 \times 10^{-19} C)^2}{r^2}$$

$$F_{gravitation} = \frac{Gm_e^2}{r^2} = (6.673 \times 10^{-11}\ Nm^2 kg^{-2}) \times \frac{(1.672 \times 10^{-27} kg)^2}{r^2}$$

$$\frac{F_{electrostatic}}{F_{gravitation}} \approx 1.2 \times 10^{36}$$

The **electrostatic repulsion** between two electrons or two protons is far stronger than the **gravitational force of attraction** between them. Therefore, in the context of interactions between individual electrons or protons, the **electrostatic force** is considered significant while the gravitational force can be ignored.



**One second after the big bang, the temperature was around 15 billion degrees Kelvin.**

The universe was filled with an extremely hot and dense primordial soup of particles and radiation. This soup is often referred to as the **"primordial plasma"** or the **"cosmic soup."**

If $k_B T >> m_0 c^2$

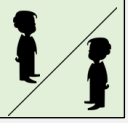
**The particle is moving relativistically**



According to **classical general relativity**, the **Big Bang** represents a **singularity**, a point of infinite density and temperature where the **laws of physics** break down. This makes it difficult to understand the **initial conditions of the universe** and explain certain observed features, such as the uniformity of the **cosmic microwave background radiation**.

**To solve the singularity problem, the well-known inflationary universe theory was developed in the 1980s**

**Because it was unable to provide a coherent explanation for light nuclear abundances and the cosmic microwave background, the steady state model was abandoned.**



The **innermost stable circular orbit** (ISCO) refers to the closest distance at which a particle can orbit the black hole in a stable circular path. For a **non-spinning black hole**, where the gravitational field can be expressed with the **Schwarzschild metric**, the radius of **ISCO** is given by:

$$R_{ISCO} = \frac{6GM}{c^2}$$

where G is the gravitational constant, M is the black-hole mass, and c is the speed of light in vacuum.

$$E = \frac{F_{Planck}}{6} \times R_{ISCO}$$

This equation states that the energy (E) of the Black hole is proportional to the radius ($R_{ISCO}$) of **ISCO** – with the constant of proportionality being $\frac{1}{6}^{th}$ of the Planck force.

If a **particle's orbit radius** is smaller than the **radius of the innermost stable circular orbit** ($R < \frac{6GM}{c^2}$), the gravitational pull of the black hole becomes so strong that the particle cannot maintain a stable circular path. Instead, it will be pulled inward toward the **singularity** at the center of the black hole.

**$R_{ISCO}$ = 3 × Schwarzschild radius of the black hole**

Let's say we have a black hole with a mass of M = one solar mass. We can calculate the radius of ISCO using the formula above.

$R_{ISCO} = 3 \times 2.9$ km $\approx$ **8.7 km**

The closest distance at which a particle can orbit the **non-rotating black hole** with a mass of **one solar mass** in a stable circular path.

✓ $R_{ISCO}$ = 2 × radius of the photon orbit

A **marginally bound orbit** refers to the closest distance at which a particle can orbit a black hole in a bound but unstable circular path. For a **Schwarzschild black hole**, the radius of **marginally bound orbit** is given by:

$$R_{mb} = \frac{4GM}{c^2} = 2 \times \text{Schwarzschild radius of the black hole}$$

where G is the gravitational constant, M is the black-hole mass, and c is the speed of light in vacuum.

$$E = \frac{F_{Planck}}{4} \times R_{mb}$$

This equation states that the energy (E) of the Black hole is proportional to the radius ($R_{mb}$) of marginally bound orbit – with the constant of proportionality being $\frac{1}{4}^{th}$ of the Planck force.

For a **black hole** with a mass of M = one solar mass:

$R_{mb}$ = 2 × 2.9 km ≈ **5.8 km**

The closest distance at which a particle can orbit the **non-rotating black hole** with a mass of **one solar mass** in a **bound but unstable** circular path – meaning that any perturbation or disturbance would cause the particle to deviate from its circular path and either plunge into the **black hole** or escape from its gravitational pull.

✓ $R_{mb} = \frac{4}{3}$ × radius of the photon orbit

✓ $R_{ISCO}$ = 1.5 $R_{mb}$

The energy, wavelength and frequency of a photon are related through the equation:

$$E = h\upsilon = \frac{hc}{\lambda}$$

The shorter the wavelength of the photon, the higher the photon energy

where $\upsilon$ and $\lambda$ denote the frequency and wavelength of the photon, respectively, h is the Planck's constant, and c the speed of photon in vacuum. The frequency and wavelength of a leV photon (with $h = 6.626 \times 10^{-34}$ Js, and $E = 1\ eV = 1.602 \times 10^{-19}$ J) are:

$$\upsilon = \frac{E}{h} = \frac{1.602 \times 10^{-19} J}{6.626 \times 10^{-34}\ Js} \approx 2.417 \times 10^{14}\ Hz$$

$$\lambda = \frac{c}{\upsilon} = \frac{2.99 \times 10^{8} m/s}{2.417 \times 10^{14}\ Hz} \approx 1.237 \times 10^{-6}\ m \approx 1237\ nm$$

A **1 eV** photon has a wavelength of $\lambda \approx 1237$ nm, and a frequency of $\upsilon \approx 2.417 \times 10^{14}$ Hz, that lies in the infrared region of the electromagnetic radiation spectrum.

**Roche's limit of the Sun** is the distance at which the gravitational pull of the Sun is sufficiently powerful enough to disturb any celestial object like comet. The Roche's limit "d" of the Sun for a comet may be obtained by the relation:

$$d = \text{radius of the Sun} \times \sqrt[3]{2 \times \frac{\text{density of the Sun}}{\text{density of a comet}}}$$

**The radius of the sphere of influence of a planet is given by:**

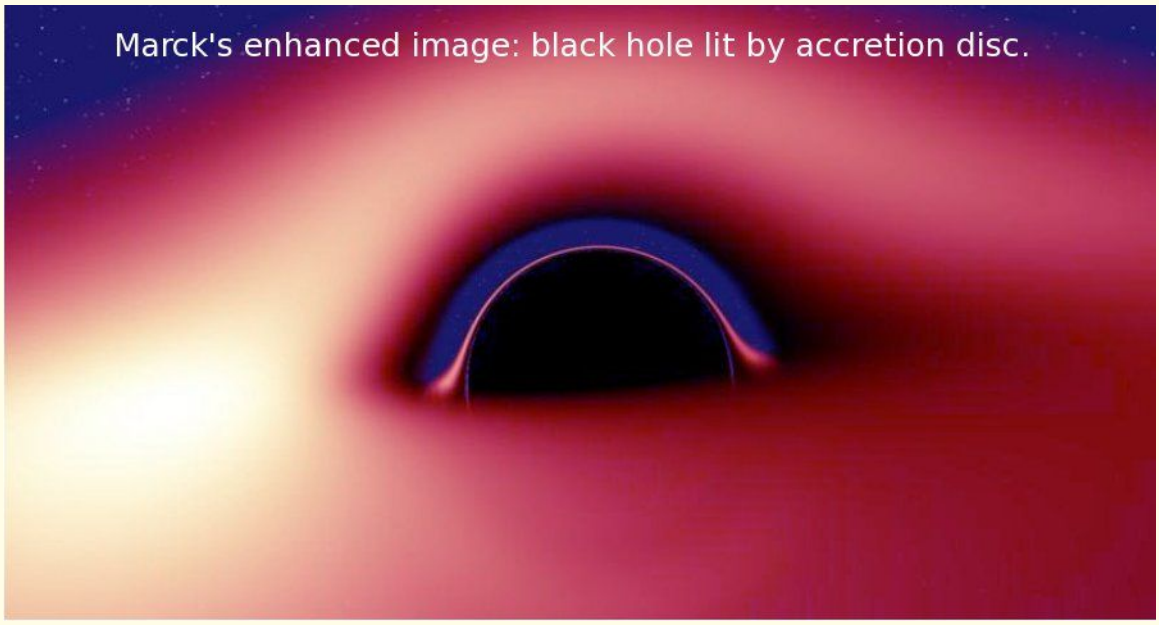
$$r_{SOI} \approx \text{radius of the planet's orbit around the Sun} \times \left(\frac{\text{Mass of the planet}}{\text{Mass of the sun}}\right)^{2/5}$$

The sphere of influence of a larger planet or a planet farther from the Sun is generally larger compared to smaller planets or those closer to the Sun.

**A star, if getting too close to a black hole, could be stretched and elongated, resembling the shape of spaghetti, due to the strong tidal forces. This is called a tidal disruption event.**

$$m = \frac{E}{c^2} = \frac{1eV}{(2.99\times10^8\ m/s)^2} = \frac{1.602\times10^{-19}\ J}{(2.99\times10^8\ m/s)^2} \approx 1.7919262648 \times 10^{-36}\ kg$$

The mass of a particle with an energy of 1 electron volt is approximately $1.7919262648 \times 10^{-36}$ kilograms, which is about 5 orders of magnitude smaller than the mass of an electron.




**Simulation by J.A. Marck of optical appearance of Schwarzschild black hole with thin (Keplerian) disk**

The **Work-Energy Theorem** states that the change in kinetic energy $\mathbf{E_K}$ of a particle as it moves from **0** to **x** is the total work done on it by force **F**:

$$dE_K = F\,dx$$

If the mass **m** is invariant, then "force is mass times acceleration": **F = ma**; however if **m** does change then force is rate of change in momentum: $\mathbf{F} = \frac{dp}{dt}$

$$dE_K = dp\,v = (v\,dm + m\,dv)\,v = v^2 dm + mv\,dv$$

Since: $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$ → $m^2c^2 - m^2v^2 = m_0^2c^2$

Differentiating both sides, we get:

$$(2m\,dm)\,c^2 - (2m\,dm)\,v^2 - m^2\,(2v\,dv) = 0$$

$$2m\,(c^2\,dm - v^2\,dm - mv\,dv) = 0$$

$$v^2\,dm + mv\,dv = c^2\,dm$$

$$dE_K = c^2\,dm$$

$$\int_0^{E_K} dE_K = c^2 \int_{m_0}^{m} dm$$

$E_K = mc^2 - m_0c^2$ → $mc^2 = m_0c^2 + E_K$




**For photon:** $m_0 = 0$

$$mc^2 = E_K$$

In the case of a photon, the total energy is entirely kinetic, as photons are massless particles that travel at the speed of light.

The thermonuclear reactions occurring inside of the sun are what produce the energy it radiates. The amount of energy the sun emits into space each day is $8.33 \times 10^{24}$ kilowatt hour. $4.14 \times 10^{15}$ kilowatt hour of this energy is delivered to the earth each day.

**Except for Pluto, all planets have almost circular orbits.**

- One of the most crucial evidence in support of the Big Bang theory (which predicts that helium should make up roughly 25% of the cosmos) is a radiation that **Penzias and Wilson** detected in 1964 and had a temperature of about 3 K.
- The universe was a hot, dense mixture of protons, electrons, neutrons, neutrinos, and photons when it was only around one second old.

**Standard Model of High Energy Physics (1928)**

↓

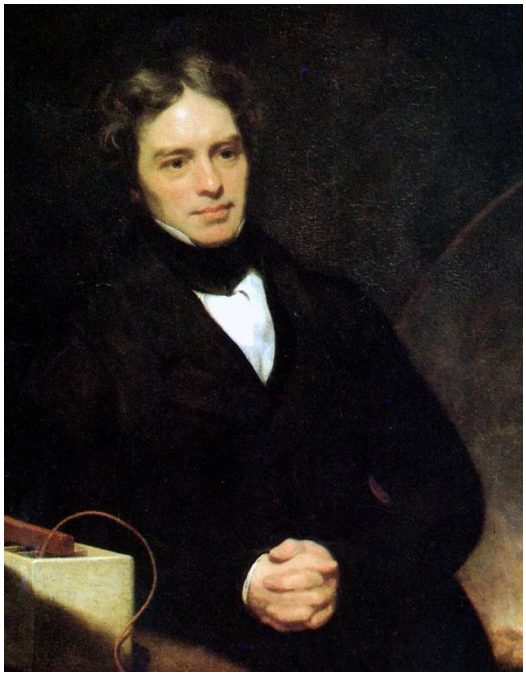
Dirac equation + Maxwell equation + Einstein equation for gravity

Despite the fact that radioactivity was known, the strong and weak interactions were not yet understood at that time

**Standard Model of High Energy Physics (1988)**

↓

Gauge theory of strong and electroweak interactions



English physicist and chemist **Michael Faraday** noticed electricity flowing through a coil in 1821 as he pushed a magnet toward or away from a coil that was attached to a galvanometer. No electricity was seen in the coil when the magnet was kept motionless close to it. Faraday postulated that a coil's fluctuating magnetic field produced a coil current. Later, **electromagnetic induction** was used to describe this phenomenon. Magnetism and electricity were linked by this.

A substance that specifically absorbs green light won't appear green. We perceive the colours that are not absorbed. The complement of the absorbed colour is said to be the observed colour. For example:

| Colour absorbed | Colour observed |
|---|---|
| Green | Purple |
| Blue | Orange |

The **First Law of Thermodynamics** states that when heat energy is transmitted from one body to another, the receiving body does work and experiences a change in internal energy. The following can be expressed mathematically: $\Delta Q = \Delta U + W$.

- ΔQ = heat energy supplied to the body
- ΔU = change in internal energy of the body
- W = work done by the body.

The direction in which the transfer occurs, that is, whether heat is moved from hotter to colder bodies or vice versa, is not provided by this law. The direction of the transfer of heat is provided by the **second law of thermodynamics**.

**Up and down quarks, electrons, and electron neutrinos make up the majority of the elements in our universe. Leptons, such as the electron, only experience the electromagnetic force and the weak beta decay force; they are not affected by the nuclear force.**



- Only electronneutrinos are produced by the sun.

**Marie Curie** gave radioactivity its name. For the purpose of separating radioactive elements from natural ores, the **Curie** invented a novel technique known as **radiochemistry**

- Using **Pauli's conception**, the Italian physicist **Enrico Fermi** created a hypothesis of beta decay in 1934 and assigned the new particle the Italian name neutrino, which means "little neutral one."

**John Dalton** proposed the idea that all matter is composed of atoms in 1803. **Albert Einstein's 1905 Brownian motion paper** was a significant turning point that helped many people come to believe in the actual existence of atoms.

**Avogadro number** → $6.023 \times 10^{23}$ $mol^{-1}$

**Number of atoms in one mole of any substance**

It would take roughly 2 billion years to count all of the atoms in a mole if we were to count them at a rate of 10 million per second.

**In the sun, 600,000,000 tons of hydrogen is consumed each second.**

**Approximately 200 times heavier than an electron, the muon was first identified in cosmic rays in 1937.**

- The weak force, which is stronger than gravitation but weaker than the electromagnetic force, is what causes radioactivity and the decay of unstable particles like muons.
- Neutrons do not experience Electrostatic repulsive force. However, people who are familiar with quantum phenomena will be aware that the **Pauli Exclusion Principle** and the **Heisenberg's uncertainty principle** really work to prevent neutrons from approaching too closely. Therefore, even neutrons cannot be held together since the nuclear attraction rapidly declines.

**If the positron and electron are moving very slowly, they may enter an orbit around one another and create the atom-like entity known as positronium. Because of its extreme instability, positronium will always result in the destruction of both the positron and the electron.**

**The most effective working theory of nature is quantum mechanics, and there is no documented example of a discrepancy between its predictions and experimentally observed findings.**

Mankind's deepest desire for scientific intervention introduced a new idea that of time. Most of the underlying assumptions of physics are concerned with time. Time may sound like a genre of fiction, but it is a well-defined genuine concept. Some argue that time is not yet discovered by us to be objective features of the mundane world: even without considering time an intrinsic feature of the mundane world, we can see that things in the physical world change, seasons change, people adapt to that drastic changes. The fact that the physical change is an objective feature of the physical world, and time is independent of under whatever circumstances we have named it. Others think time as we comprehend it does not endure beyond the bounds of our physical world. Beyond it, maybe one could run forward in time or just turn around and go back. This could probably mean that one could fall rapidly through their former selves. In a bewildering world, the question of whether the time never begin and has always been ticking, or whether it had a beginning at the big bang, is really a concern for physicists: either science could account for such an inquiry. If we find the answer to it, it would be the ultimate triumph of human justification for our continuing quest. And, our goal of a complete description of the universe we live in is self-justified. The understanding we have today is that time is not an illusion like what age-old philosophers had thought, but rather it is well defined mathematical function of an inevitable methodical framework for systematizing our experiences. If one believed that the time had a beginning, the obvious question was how it had started? The problem of whether or not the time had a beginning was a great concern to the German Philosopher, Immanuel Kant (who believed that every human concept is based on observations that are operated on by the mind so that we have no access to a mind- independent reality). He considered the entire human knowledge and came to the conclusion that time is not explored by humans to be objective features of the mundane world domain, but is a part of an inevitable systematic framework for coordinating our experiences. How and when did the time begin? No other scientific question is more fundamental or provokes such spirited debate among physicists. Since the early part of the 1900s, one explanation of the origin and fate of the universe, the Big Bang theory, has dominated the discussion. Although singularity theorem (a theorem showing that a singularity, a point where general relativity (a theory which predicts that time would come to an end inside a black hole – an invisible astrophysical entity that no one has seen, but scientists have observed gravitational evidence consistent with predictions about it, so most scientists believe it exists) breaks down, must exist under certain circumstances; in particular, that the universe must have

started with a singularity) predicted that the time, the space, and the matter or energy itself had a beginning, they didn't convey how they had a beginning. It would clearly be nice for singularity theorems if they had a beginning, but how can we distinguish whether they had a beginning? In as much as the time had a beginning at the Big Bang it would deepen implication for the role of supreme divine creator (that much of humanity worships as the source of all reality) in the grand design of creation.

But if it persists in the bounds of reason in that it has neither beginning nor end and nothing for a Creator to do. What role could ineffable benevolent creator have in creation? Life could start and new life forms could emerge on their own randomly sustaining themselves by reproducing in the environment fitted for the functional roles they perform. Personally, we're sure that the time began with a hot Big Bang. But will it go on ticking forever? If not, when it will wind up its clockwork of ticking? We're much less sure about that. However, we are just a willful gene centered breed of talking monkeys on a minor planet of a very average galaxy. But we have found a new way to question ourselves and we have learned to do them. That makes us something very special. Moreover, everything we think we understand about the universe would need to be reassessed. Every high school graduate knows cosmology, the very way we think of things, would be forever altered. The distance to the stars and galaxies and the age of the universe (13.7 billion years − number has now been experimentally determined to within 1% accuracy) would be thrown in doubt. Even the expanding universe theory, the Big Bang theory, and black holes would have to be re- examined. The Big Bang theory of universe assumes the present form of the universe originated from the hot fire ball called singularity and it assumes time did not exist before the Big Bang. But Erickcek deduced on the basis of NASA's, Wilkinson Microwave Anisotropy Probe (WMAP) that the existence of time and empty space is possible before the Big Bang.

But what would happen if you travel back in time and kill your grandfather before he conceives your father? Would the arrow of time reverse? Because motion makes the clock tick slower, can we travel back in time and kill our grandfather before he conceive our father? If not, why the universe avoids the paradox? Time Travel − Science Fiction? Taking the laws of physics and

punching them in the stomach and throwing them down the stairs – it's possible for you to break the universal speed limit. It is mind boggling to think about it – you're actually travelling backwards in time. What if you went back in time and prevented big bang from happening? You would prevent yourself from ever having been born! But then if you hadn't been born, you could not have gone back in time to prevent big bang from happening. The concept of time travel may sound something impressive and allow science fiction like possibilities for people who survived from the past, but somewhat it seems to be incredible like seeing broken tea cups gathering themselves together off the floor and jumping back on the table promoting cup manufacturers go out of business. However, travelling through time may not be the far- fetched science fiction theory. At the same time, can we open a portal to the past or find a shortcut to the future and master the time itself is still in question and forbidden by the second law of thermodynamics (which states that in any closed system like universe randomness, or entropy, never decreases with time). Of course, we have not seen anyone from the past (or have we?).

We asked how stars are powered and found the answer in the transformations of atomic nuclei. But there are still simple questions that we can ask. And one is: Is our universe merely the by-product of a cosmic accident? If the universe were merely the by-product of a grand accident, then our universe could have been a conglomeration of objects each going its own way. But everything we see in the universe obeys rules which are governed by a set of equations, without exception − which give philosophy a lot more attention than science. However, this does not mean that the universe obey rules because it exists in a plan which is created and shaped by a grinding hand.

Maybe the universe is a lucky coincidence of a grand accident emerged with ingredients such as space, time, mass, and energy exist in one-to-one correspondence with the elements of reality, and hence it obeys a set of rational laws without exception. At this moment it seems as though Dr. Science will never be able to raise the curtain on the mystery of creation. Moreover, traditional philosophy is dead, that it has not kept up with modern developments in science, and there is no reason at justifying the grinding hand because the idea of God is extremely limited and goes no further than the opening sentence of the classical theology (which has always

rejected the idea that God can classified or defined), and much is still in the speculative stage, and we must admit that there are yet no empirical or observational tests that can be used to test the idea of an accidental origin. No evidence. No scientific observation. Just a speculation. For those who have lived by their faith in the power of reason, the story may end like a bad dream since free will is just an illusion.

From the Big Bang to the Bodies such as stars or black holes including basic facts such as particle masses and force strengths, the entire universe works because the laws of physics make things happen. But if Meta or hyper laws of physics were whatever produced the universe then what produced those laws. Or perhaps, the laws, or the cause that created them, existed forever, and didn't need to be created. We must admit that there is ignorance on some issues, that is, we don't have a complete set of laws …. We are not sure exactly does the existing laws hold everywhere and at all time. Dr. Science gives us a clue, but there's no definitive answer to provide a purely natural, non-causal explanation for the existence of laws of physics and our place in it. So let's just leave it at the hypothetical laws of physics. The question, then, is why are there laws of physics? And we could say, well, that required a biblical deity, who created these laws of physics and the spark that took us from the laws of physics to the notions of time and space. Well, if the laws of physics popped into existence 13.8 billion years ago with divine help whatsoever, like theologians say, why aren't we seeing a at least one evidence of an ineffable creator in our observable universe every now and then? The origin of the Meta or hyper laws of physics remains a mystery for now. However, recent breakthroughs in physics, made possible in part by fantastic revolutionary understanding of the true nature of the mathematical quantities and theories of physics, may suggest an answer that may seem as obvious to us as the earth orbiting the sun – or perhaps as ridiculous as earth is a perfect sphere. We don't know whatever the answer may be because the Meta or hyper laws of physics are completely beyond our experience, and beyond our imagination, or our mathematics. This fact leads us to a big mystery and awaits the next generation of high energy experiments, which hope to shed light on the far-reaching answer that might be found in the laws that govern elemental particles.

**The study of the nature of light had a key role in the development of quantum mechanics.**

The significant occurrences and developments that paved the way for the emergence of quantum mechanics:

| | |
|---|---|
| Black-body radiation spectrum | (Max Planck, 1901) |
| Photoelectric effect | **(Albert Einstein, 1905)** |
| Model of the atom | (Ernest Rutherford, 1911) |
| Atomic spectra | **(Niels Bohr, 1913)** |
| Scattering of photons by electrons | (Arthur Holly Compton, 1922) |
| Exclusion principle | **(Wolfgang Ernst Pauli, 1922)** |
| Hypothesis of matter waves | (Louis de Broglie, 1925) |
| Experimental confirmation of the existence of matter waves | (C.J. Davisson and L.H. Germer, 1927) |

**In the 19th century, the wave hypothesis took over as the most popular and widely accepted explanation of how light behaves. Albert Einstein's description of the photoelectric effect and its discovery solidified the idea that radiation has a dual nature.**

- The popular **steady state hypothesis** was ultimately made redundant as a result of the discovery of the cosmic microwave background radiation.

**How is the Sun illuminated? The answer is thermonuclear fusion reaction. The only direct experimental support for this idea is the discovery of neutrinos from the Sun. This signifies the importance of neutrino detection.**

**Nuclear fusion**

↓

Four protons are fused to create an alpha particle in the overall process, along with the emission of two positrons and two neutrinos.

**Pair production**

↓

There is a chance that a photon will become an electron positron pair when its energy is more than 1.02 MeV, which is twice the rest mass of an electron. This process can take place only in the presence of Coulomb field of the nucleus which assists in balancing energy and momentum.

**The CNO cycle was recognized by German-American theoretical physicist "Hans Albrecht Bethe" as the energy source of the heavier stars in the main sequence in a seminal study that was published in March 1939 in Physical Review.**

**A piece of iron is significantly hotter than a piece of wood when they are both left in the sun for the same amount of time.**

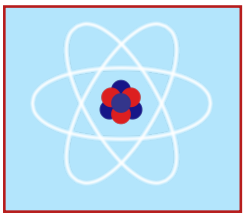
**The famed American astronomer Edwin Hubble observed that spectroscopic lines were moved to the red end as if there was some sort of Doppler redshift in 1929 while studying the spectrum of light from galaxies.**

**A proton has a mass of about 938 MeV/$c^2$, although only three of its constituents — the quarks — contribute significantly to the proton's mass; the rest is provided by the quantum chromodynamic binding energy.**

- The neutrino was hypothesized by Pauli, and Fermi incorporated it into his theory of weak interactions.
- Because it can explain why the universe only contains matter, **Cronin and Fitch's discovery of matter-antimatter asymmetry** in the weak decays of neutral kaons is of key significance.
- The **Electroweak theory** was built on the foundation of **Yang-Mills theory**, a generalization of Maxwell's electrodynamics.
- The quarks and leptons are affected by **weak interaction** at the fundamental level.
- The fact that **neutrinos** have non-zero masses was discovered as a result of neutrino oscillations.

Atoms → Nuclei → Nucleons → Quarks → ?

$10^{-8}$cm $10^{-12}$cm $10^{-13}$cm $10^{-17}$cm



**The Standard Model is currently understood to be the foundation for nearly the whole of known physics, with the exception of gravitation. It is the strong and weak nuclear forces' and electromagnetism's dynamical theory. It was created by generalizing Michael Faraday and James Maxwell's electrodynamics, which dates back a century.**

**Electrodynamics + Weak forces → Electroweakdynamics**

We have only reached $10^{-17}$ cm, compared to the fundamental scale of quantum gravity, which is $10^{-33}$ cm. The Inward driven quest is still ongoing, and we have a long way to go. The most basic issue in physics is still quantum gravity.

**The General Theory of Relativity made a number of predictions about physical events that were unthinkable before Albert Einstein. All predictions of the general theory of relativity have come true for more than a century; none have ever been disproven, whether the topic is the gravitational field's effect on light or the quantifiable effects of gravitational waves.**

4 Protons → Helium nucleus + 2 positrons + 2 neutrinos + 27 MeV

$$p + p + p + p \rightarrow 4He + e^{+} + e^{+} + \upsilon_e + \upsilon_e + 27\ MeV$$

**This can be seen as the most crucial reaction for all life forms, since without it there would be no life on Earth.**

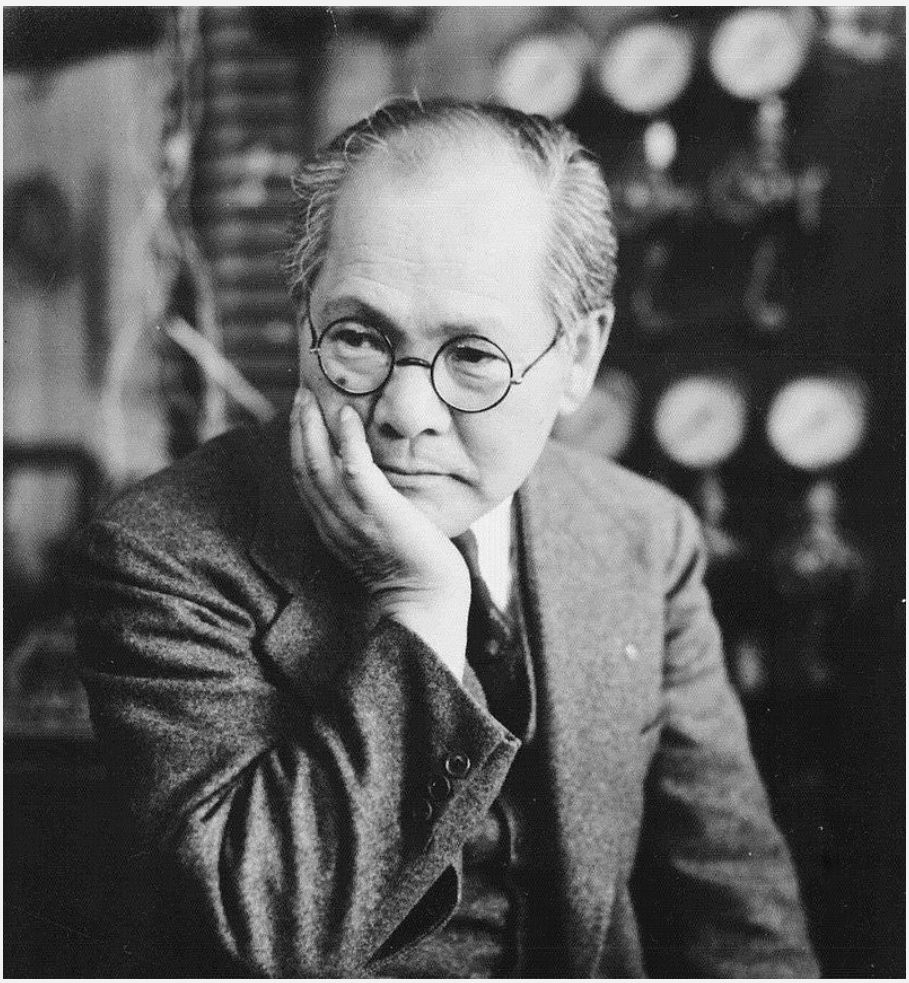
- The **Newtonian presumption** of the absoluteness of space and time was completely altered by general theory of relativity.
- **Quasisteady state cosmology** → The cosmos expands as a result of the negative energy field's ability to repel matter, as it would under the influence of a positive cosmological constant.

**Is there life elsewhere in the vast universe? Do other planets resemble Earth in any way, or are we the only beings in the vast universe? Curious minds have puzzled over these issues for centuries.**

# Chemiluminescence

The emission of light resulting from a **chemical reaction**. It occurs when the reaction produces **excited state molecules** that subsequently release energy in the form of light as they return to their ground state.

$$\underbrace{A + B}_{\text{Reactants}} \rightarrow \underbrace{AB^*}_{\text{Excited intermediate}} \rightarrow \underbrace{AB}_{\text{Product}} + \text{light}$$



## Yoshio Nishina

A highly influential Japanese physicist who is widely recognized as **"the founding father of modern physics research in Japan"** due to his significant contributions to the field.

# Snell's Law

[The law of refraction]

If the **light** enters from **medium 1** of refractive index $n_1$ to **medium 2** of refractive index $n_2$:

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

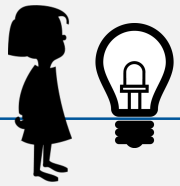
where:

- i → angle of incidence
- r → angle of refraction
- $v_1$ and $\lambda_1$ → velocity and wavelength of light in medium 1
- $v_2$ and $\lambda_2$ → velocity and wavelength of light in medium 2

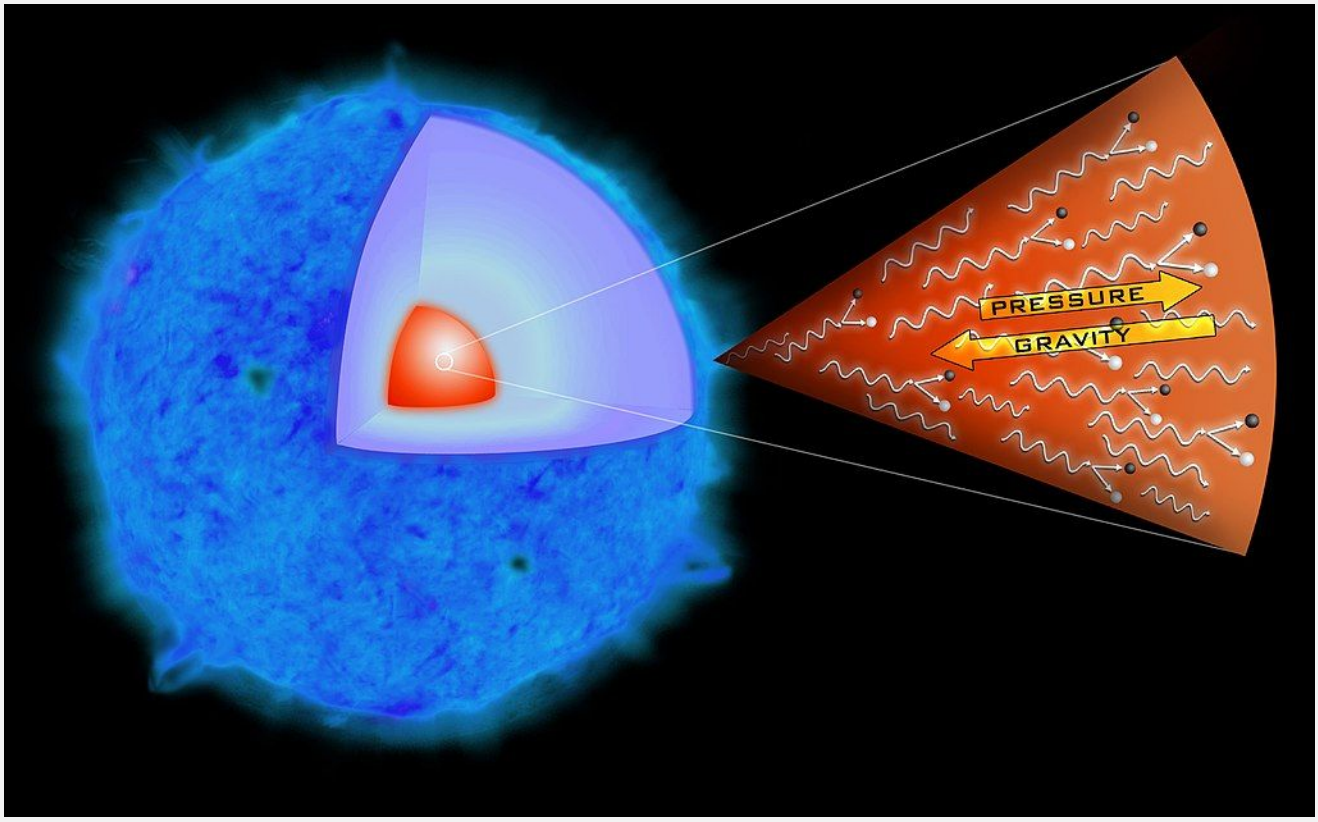
If the light is incident normally on the surface of a refracting medium:

$$i = r = 0^o$$

$$\frac{\sin i}{\sin r} = \frac{\sin 0^o}{\sin 0^o} = \frac{0}{0} \longrightarrow$$ The **Snell's Law** is meaningless.



- ✓ **Heat index of the star** = (Photovisual magnitude of a star – Radiometric magnitude of a star)
- ✓ **Colour Index of the star** = (Photographic magnitude of a star – Photovisual magnitude of a star)




In **stars** with **extremely high mass**, the intense **gamma rays** generated within their core can possess such high energy that a portion of their energy is converted into the creation of particle and antiparticle pairs. This phenomenon leads to a **reduction in radiation pressure**, causing the star to undergo a **partial collapse** due to immense gravitational pull. Following this dramatic collapse, a chain of **uncontrolled thermonuclear reactions** occurs, ultimately resulting in a powerful **stellar explosion** spraying the remains into space.

**Zurich sunspot number** = $k$ ( 10g + f )

which takes into account the variations in observations made by different observers or observatories.

where

- g is the number of groups of sunspots
- f is the number of individual sunspots.
- $k$ is a factor referred to as the **observatory factor**.

The higher the Zurich Sunspot Number, the greater the level of solar activity.

Who are we? We find that we intelligent apes who have only recently left the trees, live on an fragile planet of a humdrum star by a matter of sheer luck or by divine providence, lost in a galaxy tucked away in some forgotten corner of a universe in which there are far more galaxies than people. Sending the Beatles song across the Universe and pointing the telescopes in Deep Space Network towards the North Star, Polaris, we seek to find intellectual beings like us outside the sheer number of planets, vast ocean of existence, our solar system, and our own Milky Way galaxy. How awe hunting for them across the empty stretches of the universe would be to acquire a bit of confirmation that either we're alone in this universe or we are not. However, we are not the only life-form in the universe, is reasonable to expect since we have no reason to assume that ours is the only possible form of life. Some sort of life could have happened in a universe of greatly different form, but

Where's the evidence?



The Burden of evidence is only on the people who regard themselves as reliable witnesses that sightings of UFOs are evidence that we are being visited by someone living in another galaxy who are much more advanced enough to spread through some hundred thousand million galaxies and visit the Earth. An alien, like the teapot, is a hypothesis that requires evidence.

**The known forces of nature can be divided into four classes:**

- **Gravity:** This is the weakest of the four; it acts on everything in the universe as an attraction. And if not for this force, we would go zinging off into outer space and the sun would detonate like trillions upon trillions of hydrogen bombs.
- **Electromagnetism:** This is much stronger than gravity; it acts only on particles with an electric charge, being repulsive between charges of the same sign and attractive between charges of the opposite sign. More than half the gross national product of the earth,

representing the accumulated wealth of our planet, depends in some way on the electromagnetic force. It light up the cities of New York, fill the air with music from radios and stereos, entertain all the people in the world with television, reduce housework with electrical appliances, heat their food with microwaves, track their planes and space probes with radar, and electrify their power plants. Electromagnetism fundamentally determines all macroscopic, and many atomic levels, properties of the chemical elements, including all chemical bonding.

In a four kilogram (~1 gallon) jug of water there are $2.1 \times 10^8$ C of total electron charge. Thus, if we place two such jugs a meter apart, the electrons in one of the jugs repel those in the other jug with a force of $4.1 \times 10^{26}$ N. This force is larger than the planet Earth would weigh if weighed on another Earth. The atomic nuclei in one jug also repel those in the other with the same force. However, these repulsive forces are canceled by the attraction of the electrons in jug A with the nuclei in jug B and the attraction of the nuclei in jug A with the electrons in jug B, resulting in no net force. Electromagnetic forces are tremendously stronger than gravity but cancel out so that for large bodies gravity dominates.

- **Weak nuclear force:** This causes radioactivity and plays a vital role in the formation of the elements in stars. And a slightly stronger this force, all the neutrons in the early universe would have decayed, leaving about 100 percent hydrogen, with no deuterium for later use in the synthesizing elements in stars.
- **Strong nuclear force:** This force holds together the protons and neutrons inside the nucleus of an atom. And it is this same force that holds together the quarks to form protons and neutrons. Unleashed in the hydrogen bomb, the strong nuclear force could one day end all life on earth.

The inherent goal of unification is to show that all of these forces are, in fact, manifestations of a single super force. We can't perceive this unity at the low energies of our everyday lives, or even in our most powerful accelerators (capable of accelerating particles nearly up to the speed of light) at Fermi lab or LHC, the Large Hadron Collider, at CERN (European Centre for Nuclear

Research), in Switzerland. But close to the Big Bang temperatures, at inconceivably high energies… If the forces unify, the protons − which make up much of the mass of ordinary matter − can be unstable, and eventually decay into lighter particles such as antielectrons. Indeed, several experiments were performed in the Morton Salt Mine in Ohio to yield definite evidence of proton decay. But none have succeeded so far. However, the probability of a proton in the universe gaining sufficient energy to decay is so small that one has to wait at least a million million million million million years i.e., longer than the time since the big bang, which is about ten thousand million years.

**Relative Strength of the Four Forces:**

- Force: Nuclear
  Relative Strength: $10^{3}$

- Force: Electromagnetic
  Relative Strength: 1

- Force: Weak
  Relative Strength: $10^{-11}$

- Force: Gravitational
  Relative Strength: $10^{-39}$

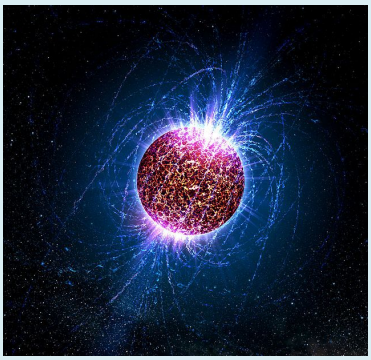
- Proton feel
  Nuclear force: Yes
  Electromagnetic force: Yes
  Weak force: No

**STRING THEORY**

↓

**All things in the cosmos are composed of vibrating strings and energy branes. This theory aims to combine general relativity and quantum physics.**

The process of Hawking radiation would take a 3 Solar mass black hole around $10^{63}$ years to entirely dissipate. This is roughly $10^{53}$ times the present age of the Universe.



Any neutron star has a magnetic field that is more than a trillion times stronger than the magnetic field of the Earth. They are regarded as the strongest magnets in the universe for this reason.

Gravitational force: Yes

- Neutron feel

  Nuclear force: Yes

  Electromagnetic force: No

  Weak force: No

  Gravitational force: Yes

- Electron feel

  Nuclear force: No

  Electromagnetic force: Yes

  Weak force: Yes

  Gravitational force: Yes

Neutron stars known as Magnetars have magnetic fields that are a thousand times stronger than those of typical neutron stars.

Star of mass M = 1.5 Solar mass and radius R = 10 km

↓

Neutron Star

Star of mass M = 1.5 Solar mass and radius R = 4.5 km

↓

Black Hole

The eminent laws do not tell us why the initial configuration was such as to produce what we observe. For what purpose? Must we turn to the anthropic principle for an explanation? Was it all just a lucky chance? That would seem a counsel of despair, a negation of all our hopes of understanding the unfathomable order of the universe. However, this is an extended metaphor for many puzzles in physics uncovered with painstaking labor, and it is especially relevant to particle physics. Still, particle physics remains unfathomable to many people and a bunch of scientists chasing after tiny invisible objects.

If string theory is correct, then every particle is nothing but a vibrating, oscillating, dancing filament named a string. A string does something aside from moving – it oscillates in different ways. Each way represents a particular mode of vibration. Different modes of vibration make the string appear as a dark energy or a cosmic ray, since different modes of vibration are seen as different masses or spins.

If Higgs theory (which is the last piece of the Standard Model that has still eluded capture – which is one of the theories LHC experimentalists hope to discover and it is the capstone for conventional big bang cosmology --which biblical creationists reject) is correct, then a new field called the Higgs field which is analogous to the familiar electromagnetic field but with new kinds of properties permits all over the space (considered the origin of mass in Grand Unified Theory – a theory that unifies the weak, strong, and electromagnetic interactions, without gravity). Different masses of the particles are due to the different strengths of interaction of the particle with the Higgs field (more the strength of interaction of the particle with the Higgs field, more the mass of the particle).To make this easier for you, let's say it is cosmic high-fructose corn syrup − the more you go through it, the heavier you get.

Which explanation is right?

Higgs theory runs rampant in the popular media claiming that String Theory Is Not The Only Game In Town. However, by the end of the decade, we will have our first glimpse of the new physics, whatever it well may be

**STRING or HIGGS**

The new physics will point to even more discoveries at the TeV scale and opens the door beyond the Standard Model and raise new questions like: if the Higgs field generate masses for the W and Z, and for the quarks and leptons − does it generate its own mass and if so how? What is its mass?

Dr. Science remains silent on the profound questions. Ultimately, however, one would hope to find complete, consistent answers that would include all the mathematical techniques as approximations. The quest for such answers is known as the grand unification of the two basic partial theories: the general theory of relativity (which states that space and time are no longer absolute, no longer a fixed background to events. Instead, they are dynamical quantities that are shaped by the matter and energy in the universe) and quantum mechanics (a theory of the microcosm which has upended many an intuition, but none deeper than this one − developed by 1900 physicists in response to a number of glaring problems that arose when 19th century conceptions of physics were applied to the microscopic world, where subatomic particles are

held together by particle like forces dancing on the sterile stage of space- time, which is viewed as an empty arena, devoid of any content). Unfortunately, however, these two theories are inconsistent with each other – i.e., quantum mechanics and general relativity do not work together. How the ideas of general relativity can be consolidated with those of quantum theory is still a? Until we progress closer toward the laws that govern our universe.

The latest theory of subatomic particles (the quantum theory) gives an estimated value of vacuum energy density that is about 120 orders of magnitude larger than the measured value — claiming our best theory cannot calculate the value of the largest energy source in the entire universe. Dr. Science advances over the wreckage of its theories by continually putting its ideas to experimental test; no matter how beautiful its idea might be; it must be discarded or modified if it is at odds with experiment. It would have been clearly be nice for quantum theory if the value of vacuum energy density were in the order of $10^{96}$ kg per cubic meter, but the measured value were in the order of $10^{-27}$ kg per cubic meter. Thus, the best candidate we have at the moment, the quantum theory, brought about its downfall by predicting the value of vacuum energy density that is about 120 orders of magnitude larger than the measured value.

We a lot of exposure with darkness and disbelief and a state of not having an immediate conclusion, and this vulnerability is of great significance, I think. When we don't comprehend the mind of nature, we are in the middle of darkness. When we have an intuitive guess as to what the outcome is; we are unsealed. And when we are fairly damn sure of what the final result is going to be, we are still in some uncertainty. And uncertainty being too complex to come about randomly is evidence for human continuing quest for justification. Sometimes, very hard, impossible things just strike and we call them thoughts. In most of the self-reproducing organisms the conditions would not be right for the generation of thoughts to predict things more or less, even if not in a simplest way, only in the few complex organisms like us spontaneous thoughts would generate and what is it that breathes fire into a perception. The human perception is enormous; it’s extensive and unlimited, and outrageous that we can ask simple questions. And they are: What the dark energy is up to? What it is about? Why this mysterious form of energy permeates all of space blowing the galaxies farther and farther apart? How accurate are the physical laws (which are essentially the same today as they were at the time of Newton despite

the scientific revolutions and paradigm shifts), which control it? Why it made the universe bang? Unfortunately, the laws that we are using are not able to answer these questions because of the prediction that the universe started off with infinite density at the big bang singularity (where all the known laws would break down). However, if one looks in a commonsense realistic point of view the laws and equations which are considered as inherent ingredients of reality − are simply the man-made ingredients introduced by the rational beings who are free to observe the universe as they want and to draw logical deductions from what they see − to describe the objective features of reality. The scientific data is fallible, changeable, and influenced by scientific understanding is refreshing. Here's an example of what I mean. In most physics textbooks we will read that the strength of the electromagnetic force is measured by the dimensionless parameter $\alpha = \frac{e^2}{4\pi\hbar c\varepsilon_0}$ (where e is the charge = $1.602 \times 10^{-19}$ Coulombs, $\varepsilon_0$ is the absolute permittivity of free space = $8.8 \times 10^{-12} \frac{F}{m}$, c is the speed of light in vacuum (an awkward conversion factor for everyday use because it's so big. Light can go all the way around the equator of the Earth in about 0.1 seconds) and ħ is the reduced Planck's constant), called the fine structure constant, which was taught to be constant became variant when the standard model of elementary particles and forces revealed that α actually varies with energy.

Quantum field theory = {Group theory + quantum mechanics}

$\lim_{N \to \infty}$ Quantum mechanics = Quantum field theory

The Quantum theory of electrodynamics (a relativistic quantum field theory or a quantum field theory – arguably the most precise theory of natural phenomena ever advanced which seems to govern everything small – through which we have been able to solidify the role of photons as the "smallest possible bundles of light" and to reveal their interactions with electrically charged particles such as electrons, in a mathematically complete, predictive, and convincing framework) and General Relativity (which dominates large things and is now called a classical theory which predicts that the universe started off with infinite density at the big bang singularity) both try to

assign mass to the singularity. But according to generally accepted history of the universe, according to what is known as the hot big bang model. At some finite time in the past i.e., between ten and twenty thousand million years ago. At this time, all matter (which is characterized by the physical quantity we define as mass) would have been on top of each other − which is called the singularity, the density would have been INFINITE. Under such conditions, all the known laws of science would break down. However, a good mathematical theory can prove anything with that amount of wiggle room, and findings are really determined by nothing except its desire. For all theoreticians and tens of thousands of university graduates at least know, the universe started off with infinite density at the hot big bang singularity with infinitely hot temperatures. And at such high temperatures that are reached in thousands of H-bomb explosions, the strong and weak nuclear forces and the gravity and electromagnetic force were all unified into a single force. What was before the Big Bang? Was the Big Bang created? If the Big Bang was not created, how was this Big Bang accomplished, and what can we learn about the agent and events of creation? Is it the product of chance or was been designed? What is it that blocked the pre-Big Bang view from us? Is Big Bang singularity an impenetrable wall and we cannot, in physics, go beyond it? To answer one question, another question arises. Erickcek's model suggests the possibility of existence of space and time before the big bang. But the world famed Big Bang theory abandons the existence of space and time before the big bang. Both the theories are consistent and based upon sophisticated experimental observations and theoretical studies. Truth must be prejudiced with honest scientific inquiry to illuminate the words of Genesis. And this is possible only if the modern scientific community would simply open its eyes to the truth.

Do black holes really exist? If they exist, why we haven't observed one hole yet? Can black holes be observed directly, and if so, how? If the production of the tiny black holes is feasible, can particle accelerators, such as the Large Hadron Collider (LHC) in Switzerland at the famed CERN nuclear laboratory create a micro black hole that will eventually eat the world? If not − if there are no black holes, what are the things we detect ripping gas off the surface of other stars? What is the structure of space-time just outside the black hole? Do their space times have horizons? : are the major questions in theoretical physics today that haunts us. The effort to

resolve these complex paradoxes is one of the very few things that lifts human mind a little above the level of farce, and gives it some of the grace of province inspiring new ideas and new experiments.

Since gravity weakens with distance, the earth pulls on your head with less force than it pulls on your feet, which are a meter or two closer to the earth's center. The difference is so tiny we cannot feel it, but an astronaut near the surface of a black hole would be literally torn apart. Most people think of a black hole as a voracious whirlpool in space, sucking down everything around it. But that's not really true! A black hole is a place where gravity has gotten so strong that even light cannot escape out of its influence.

## How a black hole might be formed?

The slightly denser regions of the nearly uniformly distributed atoms (mostly hydrogen) which lack sufficient energy to escape the gravitational attraction of the nearby atoms, would combine together and thus grow even denser, forming giant clouds of gas, which at some point become gravitationally unstable, undergo fragmentation and would break up into smaller clouds that would collapse under their own gravity. As these collapses, the atoms within them collide with one another more and more frequently and at greater and greater speeds – the gas heats up i.e., the temperature of the gas would increase, until eventually it become hot enough to start nuclear fusion reactions. And a consequence of this is that the stars like our sun (which are made up of more than one kind of gas particle) are born to radiate their energy as heat and light. But the stars with a physical radius smaller than its Schwarzschild radius further collapse to produce dark or frozen stars (i.e., the mass of a star is concentrated in a small enough spherical region, so that its mass divided by its radius exceeds a particular critical value, the resulting space-time warp is so radical that anything, including light, that gets too close to the star will be unable to escape its gravitational grip).

And these dark stars are sufficiently massive and compact and possess a strong gravitational field that prevent even light from escaping out its influence: any light emitted from the surface of the

star will be dragged back by the star's gravitational attraction before it could get very far. Such stars become black voids in space and were coined in 1969 by the American scientist John Wheeler "the black holes" (i.e., black because they cannot emit light and holes because anything getting too close falls into them, never to return). Classically, the gravitational field of the black holes (which seem to be among the most ordered and organized objects in the whole universe) is so strong that they would prevent any information including light from escaping out of their influence i.e., any information is sent down the throat of a black hole or swallowed by a black hole is forever hidden from the outside universe (this goes by the statement that "black holes have no hair" — that is, they have lost all information, all hair, except for these three parameters: its mass, spin and charge), and all one could say of the gravitational monster what the poet Dante said of the entrance to Hell: "All hope abandon, ye who enter here." Anything or anyone who falls through the black hole will soon reach the region of infinite density and the end of time. However, only the laws of classical general relativity does not allow anything (not even light) to escape the gravitational grip of the black hole but the inclusion of quantum mechanics modifies this conclusion− quantum fields would scatter off a black hole. Because energy can be created out of nothing, the pair of short-lived virtual particles (one with positive energy and the other with negative energy) appears close to the event horizon of a black hole. Spontaneous births and deaths of roiling frenzy of particles so called virtual particles momentarily occurred everywhere, all the time − violated the Energy-momentum relationship: $E^2 = m_0^2c^4 + p^2c^2$ – is the conclusion that mass and energy are interconvertible; they are two different forms of the same thing. The word virtual particles literally mean that these particles are not observed directly, but their indirect effects are measured to a remarkable degree of accuracy. Their properties and consequences are well established and well understood consequences of quantum mechanics. The gravitational might of the black hole inject energy into a pair of virtual particles ... that tears them just far enough apart so that one with negative energy gets sucked into the hole even before it can annihilate its partner ... its forsaken partner with positive energy... gets an energy boost from the gravitational force of the black hole ... escape outward to infinity (an abstract mathematical concept that was precisely formulated in the work of mathematician Georg Cantor in the late nineteenth century)... where it appear as a real particle (and to an observer at a distance, it will appear to have been emitted from the black hole). Because E= mc squared (i.e., energy is equivalent to mass), a fall of negative energy particle into the black hole therefore

reduces its mass with its horizon shrinking in size. As the black hole loses mass, the temperature of the black hole (which depends only on its mass) rises and its rate of emission of particle increases, so it loses mass more and more quickly. We don't know does the emission process continue until the black hole dissipates completely away or does it stop after a finite amount of time leaving black hole remnants.

The attempt to understand the Hawking radiation has a profound impact upon the understanding of the black hole thermodynamics, leading to the description of what the black hole entropic energy is.

**Black hole entropic energy = Black hole temperature × Black hole entropy**

$$\textbf{Black hole entropic energy} = \frac{\hbar c^3}{8\pi G M k_B} \times \frac{4\pi k_B G M^2}{\hbar c}$$

$$\textbf{Black hole entropic energy} = \frac{Mc^2}{2}$$

This means that the entropic energy makes up half of the mass energy of the black hole. For a black hole of one solar mass ($M = 2 \times 10^{30}$ kg), we get an entropic energy of $9 \times 10^{46}$ joules – much higher than the thermal entropic energy of the sun.

If a mass M is compressed into a region smaller than its **Schwarzschild radius**, then a black hole will form. The Schwarzschild radius is given by the formula:

$$R_S = \frac{2GM}{c^2}$$

where $R_S$ is the radius of the event horizon, G is the gravitational constant, M is the mass of the object, and c is the speed of light. Setting the $\frac{\text{Schwarzschild radius}}{2}$ equal to the Planck length, which is the smallest length scale that can be meaningfully defined in general relativity, we can find the mass that corresponds to the smallest possible black hole. This is known as the Planck mass.

$$\frac{GM}{c^2} = \sqrt{\frac{\hbar G}{c^3}}$$

The mass scale at which the gravitational effects become comparable to quantum mechanical effects

Solving for the mass M, we get:

$$M = \sqrt{\frac{\hbar c}{G}} \approx 2.176 \times 10^{-8}\ \text{kg}$$

Thus, the **Planck mass** can be considered as the smallest possible mass for a black hole, because any object with a mass smaller than this would not be able to form a black hole due to its Schwarzschild radius being smaller than the Planck length.

The **Compton wavelength** of a particle is a fundamental constant that describes the scale at which quantum mechanical effects become important for that particle. It is defined as:

$$\lambda_C = \frac{h}{m_0 c}$$

where $\lambda_C$ is the reduced Compton wavelength, h is Planck's constant, $m_0$ is the rest mass of the particle, and c is the speed of light.

The **Compton wavelength** gives the size of the **"quantum wave packet"** associated with the particle. Roughly speaking, it represents the minimum size of a region in space in which the position and momentum of the particle can both be known with a certain level of precision. When the size of the region becomes smaller than the **Compton wavelength**, the Heisenberg uncertainty principle requires that the momentum uncertainty becomes large, and the classical idea of position becomes meaningless.

$$\lambda_{C,e} = \frac{h}{m_e c} \approx 2.42 \times 10^{-12}\ \text{m}$$

The Compton wavelength of an electron is approximately $2.42 \times 10^{-12}$ meters. This means that the quantum mechanical wave packet associated with an electron has a minimum size of about 2.42 picometers.

One of the key pieces of evidence for the **Big Bang theory** and provides important information about the early universe.

The temperature of the **cosmic microwave background** (CMB) is approximately 2.73 Kelvin. Using **Wien's displacement law**, we can calculate the wavelength at which the radiation from the CMB is most intense. **Wien's constant** is $2.897 \times 10^{-3}$ mK, so we can calculate $\lambda_{max}$ as:

$$\lambda_{max} = \frac{\text{Wien's constant}}{T} = \frac{2.897 \times 10^{-3}\ \text{mK}}{2.73\ \text{K}} \approx 1.06\ \text{mm}$$

Therefore, the wavelength at which the radiation from the **CMB** is most intense is approximately 1.06 millimeters.

**Primordial black holes** are black holes that are thought to have formed very early in the history of the universe, shortly after the **Big Bang**. They are different from the black holes that are formed from the gravitational collapse of massive stars, which are known as stellar black holes. There are several proposed mechanisms for the formation of **primordial black holes**. One possibility is that they were formed from the gravitational collapse of large density fluctuations in the early universe. Another possibility is that they were formed from **cosmic strings**, which are one-dimensional defects in the fabric of spacetime. **Primordial black holes** are interesting because they can have a wide range of masses, including very small masses that could be as low as the **Planck mass**. Such black holes would be smaller than an atom, and would have extremely high temperatures and luminosities. They are also of interest because they could provide a

possible explanation for dark matter, which is a form of matter that does not interact with light and is thought to make up a significant fraction of the total matter in the universe. The existence of **primordial black holes** is still a matter of debate and is an active area of research in astrophysics and cosmology. However, if they do exist, they could have important implications for our understanding of the early universe and the nature of dark matter.

**Radiant flux**, also known as **radiant power**, is the total amount of radiant energy emitted, transmitted, or received per unit time, usually measured in watts. The **radiant flux** emitted or received by an object can be calculated using the following formula:

**Radiant flux = Radiant energy / Time**

where **Radiant energy** is the total amount of radiant energy emitted or received, and **Time** is the duration over which the energy is emitted or received. For example, if a light bulb emits 60 joules of radiant energy in one second, then the radiant flux emitted by the light bulb is:

**Radiant flux = Radiant energy / Time = 60 joules / 1 second = 60 watts**

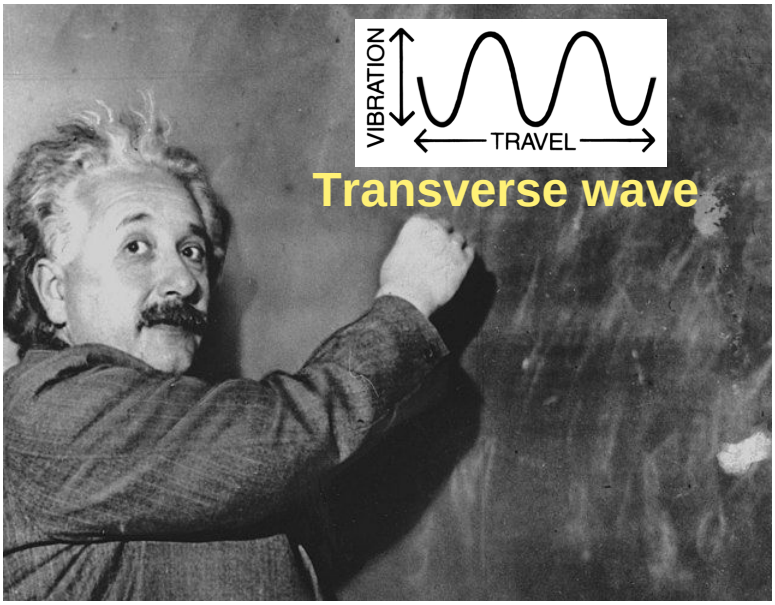
This means that the light bulb emits a radiant flux of 60 watts, which is the rate at which energy is emitted in the form of electromagnetic radiation. **Radiant flux** can also be related to the **intensity of radiation**, which is the amount of radiant flux per unit area. The intensity of radiation is usually measured in watts per square meter ($W/m^2$) and is calculated using the following formula:

**Intensity = Radiant flux / Area**

where **Area** is the surface area over which the radiant flux is distributed. For example, if the **radiant flux** emitted by the light bulb is distributed over an area of 1 square meter, then the intensity of radiation at that surface is:

**Intensity = Radiant flux / Area = 60 watts / 1 square meter = 60 $W/m^2$**

This means that the intensity of radiation at the surface is 60 watts per square meter.




What's more puzzling is that momentum can still exist even in the absence of a rest mass. From the relativistic mass and energy equation:

$$E = \sqrt{p^2c^2 + m_0^2c^4}$$

If $m_0 = 0$, then

$$E = pc$$

Since photons, gluons, and perhaps neutrinos are massless particles, they all move at the speed of light.

- Even if a particle has no rest mass, it can still possess momentum and relativistic energy.

**Free neutron → proton + electron + antineutrino**

{ The mean lifetime of a free neutron outside the atomic nucleus is around 14 minutes. }

There is a threshold temperature for each elementary particle given by: $T = \frac{m_0c^2}{k_B}$. When the universe's temperature falls below this temperature, the elementary particle is effectively removed from the universe. For proton: $T = \frac{m_0c^2}{k_B} = 1.1 \times 10^{13}$ K and so once the universe is cooled below this temperature – the proton is effectively removed from the universe.

As long as the universe's temperature is above $1.1 \times 10^{13}$ K, the following reactions can take place:

proton + antiproton ⟶ γ + γ (annihilation)

γ + γ ⟶ proton + antiproton (materialization)

Inflation predicts that density parameter = 1 and recent studies on the cosmic microwave background and evidence from supernovae support this prediction.

If we could peer into the fabric of space-time at the Planck length (the distance where the smoothness of relativity's space-time and the quantum nature of reality begin to rub up against each other), we would see the 4 dimensional fabric of space-time is simply the lowest energy state of the universe. It is neither empty nor uninteresting, and its energy is not necessarily zero **(which was discovered by Richard Dick Feynman, a colorful character who worked at the California Institute of Technology and played the bongo drums at a strip joint down the road− forwhich he received Nobel Prize for physics in 1965)**. Because $E = mc^2$, one can think that the virtual particle-antiparticle pairs of mass m are continually being created out of energy E of the 4 dimensional fabric of space-time consistent with the Heisenberg's uncertainty principle of quantum mechanics (**which tells us that from a microscopic vantage point there is a tremendous amount of activity and this activity gets increasingly agitated on ever smaller distance and time scales)**, and then, they appear together at some time, move apart, then come together and annihilate each other giving energy back to the space-time without violating the law of energy conservation (which has not changed in four hundred years and still appear in relativity and quantum mechanics). Spontaneous births and deaths of virtual particles so called quantum fluctuations occurring everywhere, all the time − is the conclusion that mass and energy are interconvertible; they are two different forms of the same thing. However, spontaneous births

and deaths of so called virtual particles can produce some remarkable problem, because infinite number of virtual pairs of mass m can be spontaneously created out of energy E of the 4 dimensional fabric of space-time, does the 4 dimensional fabric of space- time bears an infinite amount of energy, therefore, by Einstein's famous equation $E = mc^2$, does it bears an infinite amount of mass. If so, according to general relativity, the infinite amount of mass would have curved up the universe to infinitely small size. But which obviously has not happened. The word virtual particles literally mean that these particles cannot be observed directly, but their indirect effects can be measured to a remarkable degree of accuracy. Their properties and consequences are well established and well understood consequences of quantum mechanics (which states that the position of a particle is uncertain, and therefore that there is some possibility that a particle will be within an energy barrier rather than outside of it. The process of moving from outside to inside without traversing the distance between is known as quantum tunneling, and it is very important for the fusion reactions in stars like the Sun). However, they can be materialized into real particles by several ways. All that one require an energy = energy required to tear the pair apart + energy required to boost the separated virtual particle- antiparticles into real particles (i.e., to bring them from virtual state to the materialize state).

When Einstein was 26 years old, he calculated precisely how energy must change if the relativity principle was correct, and he discovered the relation $E= mc^2$ (which led to the Manhattan Project and ultimately to the bombs that exploded over Hiroshima and Nagasaki in 1945). This is now probably the only equation in physics that even people with no background in physics have at least heard of this and are aware of its prodigious influence on the world we live in. And since c is constant (because the maximum distance a light can travel in one second is 3 ×10 to the power of 8 meter), this equation tells us that mass and energy are interconvertible and are two different forms of the same thing and are in fact equivalent. Suppose a mass m is converted into energy E, the resulting energy carries mass = m and moves at the speed of light c. Hence, energy E is defined by E= mc squared. As we know c squared (the speed of light multiplied by itself) is an astronomically large number: 9 × 10 to the power of 16 meters square per second square. So if we convert a small amount of mass, we'll get a tremendous amount of energy. For example, if we convert 1kg of mass, we'll get energy of 9 × 10 to the power of 16 Joules (i.e., the energy more

than 1 million times the energy released in a chemical explosion. Perhaps since c is not just the constant namely the maximum distance a light can travel in one second but rather a fundamental feature of the way space and time are married to form space-time. One can think that in the presence of unified space and time, mass and energy are equivalent and interchangeable. But WHY? The question lingers, unanswered. Until now.

However, the equation $E = mc^2$ (where E is energy, m is mass, and c is the speed of light. People often employ this equation to calculate how much energy would be produced if, say, a bit of matter was converted into pure electromagnetic radiation. (Because the speed of light is a large number, the answer is a lot—the weight of matter converted to energy in the bomb that destroyed the city of Hiroshima was less than one ounce.) But the equation also tells us that if the energy of an object increases, so does its mass, that is, its resistance to acceleration, or change in speed) has some remarkable consequences (e.g. conversion of less than 1% of 2 pounds of uranium into energy was used in the atomic bomb over Hiroshima and body at rest still contains energy. When a body is moving, it carries an additional energy of motion called kinetic energy. In chemical and nuclear interactions, kinetic energy can be converted into rest energy, which is equivalent to generating mass. Also, the rest energy can be converted into kinetic energy. In that way, chemical and nuclear interactions can generate kinetic energy, which then can be used to run engines or blow things up). Because $E = mc^2$, the energy which a body possess due to its motion will add to its rest mass. This effect is only really significant for bodies moving at speeds close to the speed of light. For example, at 10 percent of the speed of light a body's mass M is only 0.5 percent more than its rest mass m, while at 90 percent of the speed of light it would be more than twice its rest mass. And as an body approaches the speed of light, its mass raise ever more quickly, it acquire infinite mass and since an infinite mass cannot be accelerated any faster by any force, the issue of infinite mass remains an intractable problem. For this reason all the bodies are forever confined by relativity to move at speeds slower than the speed of light. The mass m in motion at speed v is the mass $m_0$ at rest divided by the factor $\sqrt{1 - \frac{v^2}{c^2}}$ implies: the mass of a particle is not constant; it varies with changes in its velocity.

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

For non-relativistic case (v << c), the above equation reduces to:

$$m = m_0$$

Only tiny packets/particles of light (dubbed "photons" by chemist Gilbert Lewis) that have no intrinsic mass can move at the speed of light. There is little disagreement on this point. Now, being more advanced, we do not just consider conclusions like photons have no intrinsic mass. We constantly test them, trying to prove or disprove. So far, relativity has withstood every test. And try as we might, we can measure no mass for the photon. We can just put upper limits on what mass it can have. These upper limits are determined by the sensitivity of the experiment we are using to try to weigh the photon. The last number we can see that a photon, if it has any mass at all, must be less than 4 ×10 to the power of − 48 grams. For comparison, the electron has a mass of 9 × 10 to the power of − 28 grams. Moreover, if the mass of the photon is not considered to zero, then quantum mechanics would be in trouble. And it also an uphill task to conduct an experiment which proves the photon mass to be exactly zero. Tachyons the putative class of hypothetical particles (with negative mass: m < 0) is believed to travel faster than the speed of light. But, the existence of tachyons is still in question and if they exist, how can they be detected is still a? However, on one thing most physicists agree: (Just because we haven't found anything yet that can go faster than light doesn't mean that we won't one day have to eat our words. We should be more open- minded to other possibilities that just may not have occurred to us). Moreover, in expanding space − recession velocity keeps increasing with distance. Beyond a certain distance, known as the Hubble distance, it exceeds the velocity greater than the speed of light in vacuum. But, this is not a violation of relativity, because recession velocity is caused not by motion through space but by the expansion of space.

E= hυ (which implies the energy a photon can have is proportional to its frequency: larger frequency (shorter wavelength) implies larger photon energy and smaller frequency (longer wavelength) implies smaller photon energy) – because h is constant, energy and frequency of the photon are equivalent and are different forms of the same thing. And since h − which is one of

the most fundamental numbers in physics, ranking alongside the speed of light c and confines most of these radical departures from life-as-usual to the microscopic realm − is incredibly small (i.e., 6 × 10 to the power of –34 — a decimal point followed by 33 zeros and a 6 — of a joule second), the frequency of the photon is always greater than its energy, so it would not take many quanta to radiate even ten thousand megawatts. And some say the only thing that quantum mechanics **(the great intellectual achievement of the first half of this century)** has going for it, in fact, is that it is unquestionably correct. Since the **Planck's constant** is almost infinitesimally small, quantum mechanics is for little things.

Something the size of a stone of mass 1 kg moving at 100 m / s would have a quantum wavelength of $\lambda = \frac{h}{p} = \frac{6.626 \times 10^{-34} \text{Js}}{1 \text{ kg} \times 100 \text{ m/s}} = 6.626 \times 10^{-36}$ m

which is much too small for any quantum wave effects to be noticed.

**Are Neutrinos Massless?** If not they could contribute significantly to the mass of the universe? Evidence of neutrino oscillations prove that neutrinos are not massless but instead have a mass less than one hundred-thousandth that of an electron. The work on atomic science in the first thirty five years of this century took our understanding down to lengths of a millionth of a millimeter. Then we discovered that protons and neutrons are made of even smaller particles called quarks (which were named by the **Caltech physicist Murray Gell-Mann**, who won the Nobel Prize in 1969 for his work on them). We might indeed expect to find several new layers of structure more basic than the quarks and leptons that we now regard as elemental particles. Are there elementary particles that have not yet been observed, and, if so, which ones are they and what are their properties? What lies beyond the quarks and the leptons? If we find answers to them, then the entire picture of particle physics would be quite different.

Experimental evidence supporting the **Watson and Crick model** was published in a series of five articles in the same issue of Nature – caused an explosion in biochemistry and transformed the science. Of these, Franklin and Gosling's paper was the first publication of their own x-ray diffraction data and original analysis method that partially supported the Watson and Crick

model; this issue also contained an article on DNA (a main family of polynucleotides in living cells) structure by Maurice Wilkins and two of his colleagues, whose analysis supported their double-helix molecular model of DNA. In 1962, after Franklin's death, Watson, Crick, and Wilkins jointly received the Nobel Prize in Physiology or Medicine. From each gene's point of view, the 'background' genes are those with which it shares bodies in its journey down the generations. DNA (deoxyribonucleic acid) – which is known to occur in the chromosomes of all cells (whose coded characters spell out specific instructions for building willow trees that will shed a new generation of downy seeds). Most forms of life including vertebrates, reptiles, Craniates or suckling pigs, chimps and dogs and crocodiles and bats and cockroaches and humans and worms and dandelions, carry the amazing complexity of the information within the some kind of replicator—molecules called DNA in each cell of their body, that a live reading of that code at a rate of one letter per second would take thirty-one years, even if reading continued day and night. Just as protein molecules are chains of amino acids, so DNA molecules are chains of nucleotides. Linking the two chains in the DNA, are pairs of nucleic acids (purines + pyrimidines). There are four types of nucleic acid, adenine "A", cytosine "C", guanine "G", and thiamine "T." An adenine (purine) on one chain is always matched with a thiamine (pyrimidine) on the other chain, and a guanine (purine) with a cytosine (pyrimidine). Thus DNA exhibits all the properties of genetic material, such as replication, mutation and recombination. Hence, it is called the molecule of life. We need DNA to create enzymes in the cell, but we need enzymes to unzip the DNA. Which came first, proteins or protein synthesis? If proteins are needed to make proteins, how did the whole thing get started? We need precision genetic experiments to know for sure.

A theory is a good theory if it satisfies one requirement. It must make definite predictions about the results of future observations. Basically, all scientific theories are scientific statements that predict, explain, and perhaps describe the basic features of reality. Despite having received some great deal, discrepancies frequently lead to doubt and discomfort. For example, the most precise estimate of sun’s age is around 10 million years, based on linear density model. But geologists have the evidence that the formation of the rocks, and the fossils in them, would have taken hundreds or thousands of millions of years. This is far longer than the age of the Earth, predicted

by linear density model. Hence the earth existed even before the birth of the sun! Which is absolutely has no sense. The linear density model therefore fails to account for the age of the sun. Any physical theory is always provisional, in the sense that it is only a hypothesis: it can be disproved by finding even a single observation that disagrees with the predictions of the theory. Towards the end of the nineteenth century, physicists thought they were close to a complete understanding of the universe. They believed that entire universe was filled by a hypothetical medium called the ether. As a material medium is required for the propagation of waves, it was believed that light waves propagate through ether as the pressure waves propagate through air. Soon, however, inconsistencies with the idea of ether begin to appear. Yet a series of experiments failed to support this idea. The most careful and accurate experiments were carried out by two Americans: Albert Michelson and Edward Morley (who showed that light always traveled at a speed of one hundred and eighty six thousand miles a second (no matter where it came from) and disproved Michell and Laplace's idea of light as consisting of particles, rather like cannon balls, that could be slowed down by gravity, and made to fall back on the star) at the Case School of Applied Science in Cleveland, Ohio, in 1887 − which proved to be a serve blow to the existence of ether. All the known subatomic particles in the universe belong to one of two groups, Fermions or bosons. Fermions are particles with integer spin ½ and they make up ordinary matter. Their ground state energies are negative. Bosons are particles (whose ground state energies are positive) with integer spin 0, 1, 2 and they act as the force carriers between fermions (For example: The electromagnetic force of attraction between electron and a proton is pictured as being caused by the exchange of large numbers of virtual massless bosons of spin 1, called photons).

**Positive ground state energy of bosons plus negative ground state energy of fermions = 0**

But Why? May be because to eliminate the biggest infinity in supergravity theory (the theory which introduced a superpartner to the conjectured subatomic particle with spin 2 that is the quanta of gravity "the graviton" (called the gravitino, meaning "little graviton," with spin $\frac{3}{2}$) – that even inspired one of the most brilliant theoretical physicists since Einstein “Stephen

Hawking" to speak of "the end of theoretical physics" being in sight when he gave his inaugural lecture upon taking the Lucasian Chair of Mathematics at Cambridge University, the same chair once held by Isaac Newton – a person who developed the theory of mechanics, which gave us the classical laws governing machines which in turn, greatly accelerated the Industrial Revolution, which unleashed political forces that eventually overthrew the feudal dynasties of Europe)?

There is strong evidence ... that the universe is permeated with dark matter approximately six times as much as normal visible matter (i.e. invisible matter became apparent in 1933 by Swiss astronomer Fritz Zwicky – which can be considered to have energy, too, because $E = mc^2$ – exist in a huge halo around galaxies and does not participate in the processes of nuclear fusion that powers stars, does not give off light and does not interact with light but bend starlight due to its gravity, somewhat similar to the way glass bends light). Although we live in a dark matter dominated universe (i.e., dark matter, according to the latest data, makes up 23 percent of the total matter/energy content of the universe) experiments to detect dark matter in the laboratory have been exceedingly difficult to perform because dark matter particles such as the neutralino, which represent higher vibrations of the superstring – interact so weakly with ordinary matter. Although dark matter was discovered almost a century ago, it is still a mystery shining on library shelves that everyone yearns to resolve.

Opening up the splendor of the immense heavens for the first time to serious scientific investigation. On the short time scale of our lives, not surprisingly, we underwent many transformations in our slow, painful evolution, an evolution often overshadowed by religious dogma and superstition to seek the answer to the question from the beginnings of our understanding. No progress was made in any scientific explanations because the experimental data were non-existent and there were no theoretical foundations that could be applied. In the latter half of the 20th century, there were several attempts such as quantum mechanics (the theory of subatomic physics and is one of the most successful theories of all time which is based on three principles: (1) energy is found in discrete packets called quanta; (2) matter is based on point particles but the probability of finding them is given by a wave, which obeys the

Schrödinger wave equation; (3) a measurement is necessary to collapse the wave and determine the final state of an object), the "big bang," probability theory, the general relativity (a theoretical framework of geometry which has been verified experimentally to better than 99.7 percent accuracy and predicts that the curvature of space-time gives the illusion that there is a force of attraction called gravity) to adjust to ensure agreement with experimental measurements and answer the questions that have so long occupied the mind of philosophers (from Aristotle to Kant) and scientists. However, we must admit that there is ignorance on some issues, for example, "we don't have a complete theory of universe which could form a framework for stitching these insights together into a seamless whole – capable of describing all phenomena…. We are not sure exactly how universe happened." However, the generally accepted history of the universe, according to what is so-called the big bang theory (proposed by a Belgian priest, Georges Lemaître, who learned of Einstein's theory and was fascinated by the idea that the theory logically led to a universe that was expanding and therefore had a beginning) has completely changed the discussion of the origin of the universe from almost pure speculation to an observational subject. In such model one finds that our universe started with an explosion. This was not any ordinary explosion as might occur today, which would have a point of origin (center) and would spread out from that point. The explosion occurred simultaneously everywhere, filling all space with infinite heat and energy. At this time, order and structure were just beginning to emerge – the universe was hotter and denser than anything we can imagine (at such temperatures and densities (of about a trillion trillion trillion trillion trillion trillion (1 with 72 zeros after it) tons per cubic inch) gravity and quantum mechanics were no longer treated as two separate entities as they were in point-particle quantum field theory, the four known forces were unified as one unified super force) and was very rapidly expanding much faster than the speed of light (this did not violate Einstein's dictum that nothing can travel faster than light, because it was empty space that was expanding) and cooling in a way consistent with Einstein field equations. As the universe was expanding, the temperature was decreasing. Since the temperature was decreasing, the universe was cooling and its curvature energy was converted into matter like a formless water vapor freezes into snowflakes whose unique patterns arise from a combination of symmetry and randomness. Approximately $10^{-37}$ seconds into the expansion, a phase transition caused a cosmic inflation, during which the universe underwent an incredible amount of superliminal expansion and grew exponentially by a factor $e^{3Ht}$ (where H was a

constant called Hubble parameter and t was the time) – just as the prices grew by a factor of ten million in a period of 18 months in Germany after the First World War and it doubled in size every tiny fraction of a second – just as prices double every year in certain countries. After inflation stopped, the universe was not in a de Sitter phase and its rate of expansion was no longer proportional to its volume since H was no longer constant. At that time, the entire universe had grown by an unimaginable factor of $10^{50}$ and consisted of a hot plasma "soup" of high energetic quarks as well as leptons (a group of particles which interacted with each other by exchanging new particles called the W and Z bosons as well as photons). And quarks and gluons were "deconfined" and free to move over distances much larger than the hadron size (>>1 fm) in a soup called quark gluon plasma (QGP). There were a number of different varieties of quarks: there were six "flavors," which we now call up, down, strange, charmed, bottom, and top. And among the leptons the electron was a stable object and muon (that had mass 207 times larger than electron and now belongs to the second redundant generation of particles found in the Standard Model) and the tauon (that had mass 3,490 times the mass of the electron) were allowed to decay into other particles. And associated to each charged lepton, there were three distinct kinds of ghostly particles called neutrinos (the most mysterious of subatomic particles, are difficult to detect because they rarely interact with other forms of matter. Although they can easily pass through a planet or solid walls, they seldom leave a trace of their existence. Evidence of neutrino oscillations prove that neutrinos are not massless but instead have a mass less than one- hundred-thousandth that of an electron):

- the electron neutrino (which was predicted in the early 1930s by Wolfgang Pauli and discovered by Frederick Reines and Clyde Cowan in mid-1950s)
- the muon neutrino (which was discovered by physicists when studying the cosmic rays in late 1930s)
- the tauon neutrino (a heavier cousin of the electron neutrino)

Temperatures were so high that these quarks and leptons were moving around so fast that they escaped any attraction toward each other due to nuclear or electromagnetic forces. However,

they possessed so much energy that whenever they collided, particle – antiparticle pairs of all kinds were being continuously created and destroyed in collisions. And the uncertainty in the position of the particle times the uncertainty in its velocity times the mass of the particle was never smaller than a certain quantity, which was known as Planck's constant. Similarly, $\Delta E \times \Delta t$ was $\geq \frac{h}{4\pi}$ (where h was a quantity called Planck's constant and $\pi = 3.14159 \ldots$ was the familiar ratio of the circumference of a circle to its diameter). Hence the Heisenberg's uncertainty principle (which captures the heart of quantum mechanics – i.e. features normally thought of as being so basic as to be beyond question (e.g. that objects have definite positions and speeds and that they have definite energies at definite moments) are now seen as mere artifacts of Planck's constant being so tiny on the scales of the everyday world) was a fundamental, inescapable property of the universe. At some point an unknown reaction led to a very small excess of quarks and leptons over antiquarks and antileptons — of the order of one part in 30 million. This resulted in the predominance of matter over antimatter in the universe. The universe continued to decrease in density and fall in temperature, hence the typical energy of each particle was decreased in inverse proportion to the size of the universe (since the average energy – or speed – of the particles was simply a measure of the temperature of the universe). The symmetry (a central part of the theory [and] its experimental confirmation would be a compelling, albeit circumstantial, piece of evidence for strings) however, was unstable and, as the universe cooled, a process called spontaneous symmetry breaking phase transitions placed the fundamental forces of physics and the parameters of elementary particles into their present form. After about $10^{-11}$ seconds, the picture becomes less speculative, since particle energies drop to values that can be attained in particle physics experiments. At about $10^{-6}$ seconds, there was a continuous exchange of smallest constituents of the strong force called gluons between the quarks and this resulted in a force that pulled the quarks to form little wisps of matter which obeys the strong interactions and makes up only a tiny fraction of the matter in the universe and is dwarfed by dark matter called the baryons ( protons – a positively charged particles very similar to the neutrons, which accounts for roughly half the particles in the nucleus of most atoms − and neutrons – a neutral subatomic particles which, along with the protons, makes up the nuclei of atoms – belonged to the class baryons) as well as other particles. The small excess of quarks over antiquarks led to a small excess of baryons over antibaryons. The proton was composed of two up quarks and one

down quark and the neutron was composed of two down quarks and one up quark. And other particles contained other quarks (strange, charmed, bottom, and top), but these all had a much greater mass and decayed very rapidly into protons and neutrons. The charge on the up quark was = $+\frac{2}{3}$ e and the charge on the down quark was = $-\frac{1}{3}$ e. The other quarks possessed charges of $+\frac{2}{3}$ e or $-\frac{1}{3}$ e. The charges of the quarks added up in the combination that composed the proton but cancelled out in the combination that composed the neutron i.e.,

$$\text{Proton charge was} = \left(\frac{2}{3}e\right) + \left(\frac{2}{3}e\right) + \left(-\frac{1}{3}e\right) = e$$

$$\text{Neutron charge was} = \left(\frac{2}{3}e\right) + \left(-\frac{1}{3}e\right) + \left(-\frac{1}{3}e\right) = 0$$

And the force that confined the rest mass energy of the proton or the neutron to its radius was so strong that it is now proved very difficult if not impossible to obtain an isolated quark. As we try to pull them out of the proton or neutron it gets more and more difficult. Even stranger is the suggestion that the harder and harder if we could drag a quark out of a proton this force gets bigger and bigger – rather like the force in a spring as it is stretched causing the quark to snap back immediately to its original position. This property of confinement prevented one from observing an isolated quark (and the question of whether it makes sense to say quarks really exist if we can never isolate one was a controversial issue in the years after the quark model was first proposed). However, now it has been revealed that experiments with large particle accelerators indicate that at high energies the strong force becomes much weaker, and one can observe an isolated quark. In fact, the standard model (one of the most successful physical theories of all time and since it fails to account for gravity (and seems so ugly), theoretical physicists feel it cannot be the final theory) in its current form requires that the quarks not be free. The observation of a free quark would falsify that aspect of the standard model, although nicely confirm the quark idea itself and fits all the experimental data concerning particle physics without exception. Each quark possessed baryon number = $\frac{1}{3}$ : the total baryon number of the proton or the neutron was the sum of the baryon numbers of the quarks from which it was composed. And the electrons and neutrinos contained no quarks; they were themselves truly

fundamental particles. And since there were no electrically charged particles lighter than an electron and a proton, the electrons and protons were prevented from decaying into lighter particles – such as photons (that carried zero mass, zero charge, a definite energy E = pc and a momentum p = mc) and less massive neutrinos (with very little mass, no electric charge, and no radius — and, adding insult to injury, no strong force acted on it). And a free neutron being heavier than the proton was not prevented from decaying into a proton (plus an electron and an antineutrino). The temperature was now no longer high enough to create new proton– antiproton pairs, so a mass annihilation immediately followed, leaving just one in $10^{10}$ of the original protons and neutrons, and none of their antiparticles (i.e., antiparticle was sort of the reverse of matter particle. The counterparts of electrons were positrons (positively charged), and the counterparts of protons were antiprotons (negatively charged). Even neutrons had an antiparticle: antineutrons. A similar process happened at about 1 second for electrons and positrons (positron: the antiparticle of an electron with exactly the same mass as an electron but its electric charge is +1e). After these annihilations, the remaining protons, neutrons and electrons were no longer moving relativistically and the energy density of the universe was dominated by photons − (what are sometimes referred to as the messenger particles for the electromagnetic force) − with a minor contribution from neutrinos. The density of the universe was about $4 \times 10^9$ times the density of water and much hotter than the center of even the hottest star – no ordinary components of matter as we know them – molecules, atoms, nuclei – could hold together at this temperature. And the total positive charge due to protons plus the total negative charge due to electrons in the universe was = 0 (Just what it was if electromagnetism would not dominate over gravity and for the universe to remain electrically neutral). Everything was quantum. Subatomic particle behavior was governed by quantum mechanics, which produced different rules of physics for the very small entities. Without quantum mechanics, atoms would have not existed. The electrons, as they whizz around the nucleus, would have lost energy and collapsed into the center, destroying the atom. However, quantum mechanics prevented this from happening.

And a few minutes into the expansion, when the temperature was about a billion (one thousand million; 10 to the power of 9) kelvin and the density was about that of air, protons and neutrons no longer had sufficient energy to escape the attraction of the strong nuclear force and they

started to combine together to produce the universe's deuterium and helium nuclei in a process called Big Bang nucleosynthesis. And most of the protons remained uncombined as hydrogen nuclei. And inside the tiny core of an atom, consisting of protons and neutrons, which was roughly 10 −13 cm across or roughly an angstrom, a proton was never permanently a proton and also a neutron was never permanently a neutron. They kept on changing into each other. A neutron emitted a π meson (a particle predicted by **Hideki Yukawa** (for which he was awarded the Nobel Prize in physics in 1949) – composed of a quark and antiquark, which is unstable because the quark and antiquark can annihilate each other, producing electrons and other particles) and became proton and a proton absorbed a π meson and became a neutron. That is, the exchange force resulted due to the absorption and emission of π mesons kept the protons and neutrons bound in the nucleus. And the time in which the absorption and emission of π mesons took place was so small that ***π* mesons** were not detected. And a property of the strong force called asymptotic freedom caused it to become weaker at short distances. Hence, although quarks were bound in nuclei by the strong force, they moved within nuclei almost as if they felt no force at all.

Within only a few hours of the big bang, the Big Bang nucleosynthesis stopped. And after that, for the next million years or so, the universe just continued expanding, without anything much happening. Eventually, once the temperature had dropped to a few thousand degrees, there was a continuous exchange of virtual photons **(whose existence is determined by the Heisenberg's uncertainty principle and possessed some characteristics similar to the original photons)** between the nuclei and the electrons. And the exchange was good enough to produce — what else? — A electrostatic force of attraction $-\frac{Ze^2}{4\pi\varepsilon_0 r^2}$ — that pulled the electrons towards the nuclei to form neutral atoms (the basic unit of ordinary matter, made up of a tiny nucleus **(consisting of protons and neutrons)** surrounded by orbiting electrons). And these atoms reflected, absorbed, and scattered light and the resulted light was red shifted by the expansion of the universe towards the microwave region of the electromagnetic spectrum. And there was cosmic microwave background radiation (which, through the last 15 billion years of cosmic expansion, has now cooled to a mere handful of degrees above **absolute zero** (–273ºC − the lowest possible temperature, at which substances contain no heat energy and all vibrations stop—almost: the water molecules are as fixed in their equilibrium positions as quantum

uncertainty allows) and today, scientists measure tiny deviations within this background radiation to provide evidence for inflation or other theories).

The irregularities in the universe meant that some regions of the nearly uniformly distributed atoms had slightly higher density than others. The gravitational attraction of the extra density slowed the expansion of the region, and eventually caused the region to collapse to form galaxies and stars. And the nuclear reactions in the stars transformed hydrogen to helium (composed of two protons and two neutrons and symbolized by ${}_2He^4$, highly stable—as predicted by the rules of quantum mechanics) to carbon (with their self- bonding properties, provide the immense variety for the complex cellular machinery— no other element offers a comparable range of possibilities) with the release of an enormous amount of energy via Einstein's equation $E = mc^2$. This was the energy that lighted up the stars. And the process continued converting the carbon to oxygen to silicon to iron. And the nuclear reaction ceased at iron. And the star experienced several chemical changes in its innermost core and these changes required huge amount of energy which was supplied by the severe gravitational contraction. And as a result the central region of the star collapsed to form a neutron star. And the outer region of the star got blown off in a tremendous explosion called a supernova, which outshone an entire galaxy of 100 billion stars, spraying the manufactured elements into space. And these elements provided some of the raw material for the generation of cloud of rotating gas which went to form the sun and a small amount of the heavier elements collected together to form the asteroids, stars, comets, and the bodies that now orbit the sun as planets like the Earth and their presence caused the fabric of space around them to warp (more massive the bodies, the greater the distortion it caused in the surrounding space). The massive bodies that were accelerated caused the emission of gravity waves, ripples in the curvature of 4 dimensional fabric of space-time that traveled away in all directions like waves in a lake at a specific speed, the speed of light. Like light, gravity waves carried energy away from the bodies that emit them. The equation: $\boxed{\frac{E}{B} = c}$ successfully united electricity and magnetism in the framework of the electromagnetic field and asserted electromagnetic disturbances travel at a fixed and never-changing speed equal to that of light. The universe became disorderly as time went on. The total entropy of the universe $S_{uni}$, was

continually increasing with time and entropic energy of the universe was never less than or greater than $TS_{uni}$ but = $TS_{uni}$. The universe obeyed the second law of thermodynamics:

$$dS_{uni} \geq 0$$

and continued to expand and headed towards an ultimate "Heat Death" or "Big Chill". The stars were shining, supernovae were exploding, black holes were forming, winds on planetary surfaces were blowing dust around, and hot things like coffee mugs were cooling down and the cosmological arrow of time pointed in the direction of the universe's expansion. The space was simply the lowest energy state of the universe. It was neither empty nor uninteresting, and its energy was not necessarily zero

- Below Planck Time: $\sqrt{\frac{\hbar G}{c^5}}$
- Below Planck Length: $\sqrt{\frac{\hbar G}{c^3}}$
- Above Planck Temperature: $\sqrt{\frac{\hbar c^5}{G k_B^2}}$

All the known laws of physics were meaningless. The Planck units were characteristic of the properties of the Universe during its first moments.

At time $\rightarrow \sqrt{\frac{\hbar G}{c^5}}$

- The Universe was at the Planck temperature.
- The mean energy of photons was close to the Planck energy $\sqrt{\frac{\hbar c^5}{G}}$.

The earth was initially very hot and without an atmosphere. In the course of time the planet earth produced volcanoes and the volcanoes emitted water vapor, carbon dioxide and other gases. And there was an atmosphere. This early atmosphere contained no oxygen, but a lot of other gases and among them some were poisonous, such as hydrogen sulfide (the gas that gives rotten eggs their smell). And the sunlight dissociated water vapor and there was oxygen. And carbon dioxide

in excess heated the earth and balance was needed. So carbon dioxide dissolved to form carbonic acid and carbonic acid on rocks produced limestone and subducted limestone fed volcanoes that released more carbon dioxide. And there was high temperature and high temperature meant more evaporation and dissolved more carbon dioxide. And as the carbon dioxide turned into limestone, the temperature began to fall. And a consequence of this was that most of the water vapor condensed and formed the oceans. And the low temperature meant less evaporation and carbon dioxide began to build up in the atmosphere. And the cycle went on for billions of years. And after the few billion years, volcanoes ceased to exist. And the molten earth cooled, forming a hardened, outer crust. And the earth's atmosphere consisted of nitrogen, oxygen, carbon dioxide, plus other miscellaneous gases (hydrogen sulfide, methane, water vapor, and ammonia). And then a continuous electric current through the atmosphere simulated lightning storms. And some of the gases came to be arranged in the form of more complex organic molecules such as simple amino acids (the basic chemical subunit of proteins, when, when linked together, formed proteins) and carbohydrates (which were very simple sugars). And the water vapor in the atmosphere probably caused millions of seconds of torrential rains, during which the organic molecules reached the earth. And it took two and a half billion years for an ooze of organic molecules to react and built earliest cells as a result of chance combinations of atoms into large structures called macromolecules and then advance to a wide variety of one – celled organisms, and another billion years to evolve through a highly sophisticated form of life to primitive mammals endowed with two elements: genes (a set of instructions that tell them how to sustain and multiply themselves), and metabolism (a mechanism to carry out the instructions). But then evolution seemed to have speeded up. It only took about a hundred million years to develop from the early mammals (the highest class of animals, including the ordinary hairy quadrupeds, the whales and Mammoths , and characterized by the production of living young which are nourished after birth by milk from the teats (MAMMAE, MAMMARY GLANDS) of the mother) to Homosapiens. This picture of a universe that started off very hot and cooled as it expanded (like when things are compressed they heat up ... and, when things ... expand ... they cool down) is in agreement with all the observational evidence which we have today (and it explains Olbers' paradox: The paradox that asks why the night sky is black. If the universe is infinite and uniform, then we must receive light from an infinite number of stars, and hence the

sky must be white, which violates observation). Nevertheless, it leaves a number of important questions unanswered:

- Why the universe started off very hot i.e., why it violently emerged from a state of infinite compression? Why is the universe the same everywhere i.e., looks the same from every point (homogeneous) and looks the same in every direction (isotropic)? If the cosmic inflation made the universe flat, homogeneous and isotropic, then what is the hypothetical field that powered the inflation? What are the details of this inflation?

Where did the physical laws originate? Is it reasonable to discuss the cosmos before the big bang? Does the circumstance of the time of creation affect how the laws of quantum theory apply? What is time?

- Much is explained by protons and electrons. But there remains the neutrino…

$\approx 10^9$ neutrinos / proton. What is their physical picture in the universe?

**What is our physical place in the universe?**

Present 13.8 billion years after the Big Bang

We can only see the surface of the sky where light was scattered.

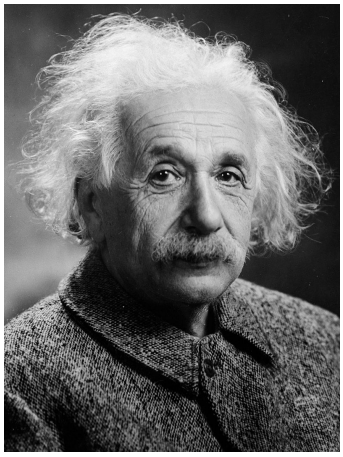
The big bang theory, on its own, cannot explain these features or answer these questions because of its prediction that the universe started off with infinite density at the big bang singularity. At the singularity (a state of infinite gravity), all the known physical laws of cosmology would break down: one couldn't predict what would come out of the infinitely dense Planck-sized nugget called the singularity. The search for the origin and fate of the universe (which is determined by whether the Omega ($\Omega_0$) density parameter is less than, equal to or greater than 1) is a distinctly human drama, one that has stretched the mind and enriched the spirit. We (a species ruled by all sorts of closer, warmer, ambitions and perceptions) are all, each in our own way, seekers of an absolute limit of scientific explanation (that may never be achieved) and we each long for an answer to why we exist... as our future descendants marvels at our new view of the universe ... we are... contributing our wrong to the human letter reaching for the stars. In the millennia of Homo sapiens evolution, we have found it something quite . . . puzzling. Even that

great Jewish scientist Albert Einstein (who freed us from the superstition of the past and interpreted the constancy of the speed of light as a universal principle of nature that contradicted Newtonian theory) sustained a mystical outlook on the universe that was, he said, constantly renewed from the wonder and humility that filled him when he gazed at the universe. I wonder, can our finite minds ever truly understand such things as mysticism and infinity?

Undisturbed space + rigid mass → distorted space

$$G_{\alpha\beta} + g_{\alpha\beta}\Lambda = \frac{8\pi G}{c^4} T_{\alpha\beta}$$

- $G_{\alpha\beta}$ → curvature of space
- $T_{\alpha\beta}$ → distribution of mass and energy
- $\frac{8\pi G}{c^4}$ → constant
- $\Lambda$ → cosmological constant
- $g_{\alpha\beta}$ → spacetime geometry



Albert Einstein

**This equation describe gravity as a result of spacetime being curved by the distribution of matter and energy within it.**

The universe is a pretty big place seems like an awful waste of space.

- **Nearest star:** 4.22 light years.
- **Nearest galaxy:** 2.44 million light years.
- Galaxies within our horizon are now 40 billion light years away.
- Universe beyond horizon: 10 to the 10 to the 100 times bigger.

The Goldilocks Planet is not all that well suited for human life.

- $\frac{2}{3}$ salt water unfit for drinking.
- Humans are restricted only to surface.

- Atmosphere does not block harmful ultraviolet radiation which causes skin cancer and other genetic disorders.
- Natural calamities like floods, earthquakes, famine and droughts, diseases like cancer, AIDS, kill millions millions of people yearly.
- Only two photons of every billion emitted by sun are used to warm the Earth surface, the rest radiating uselessly into space. And lack of oxygen and cosmic microwave background radiation (which is well characterized by a (2.728 ± 0.002) Kelvin black body spectrum over more than three decades in frequency) prevents humans from spending years in outer space.

The fine tuning coincidences are updated and refurbished and have been somewhat misleadingly categorized under the designation anthropic principle, a term coined by astronomer Brandon Carter in 1974 – which states that the physical properties of the universe are as they are because they permit the emergence of life. This teleological principle tries to explain why some physical properties of matter seem so fine-tuned as to permit the existence of life -- and are widely claimed to provide prima facie evidence for purposeful design—a design with life and perhaps humanity in mind. However, fine tuning coincidences are only needed to fill in the details of evidence for the existence of insulated interpositions of Divine power. If the universe were congenial to human life, then we would expect it to be easy for humanlike life to develop and survive throughout the vast stretches of the universe (an intricately complex place). We must admit that much of what we believe, including our fundamental coincidences about the universe is a blind leap of faith. We, after all, carbon-based biological systems operating a billion times slower than computer chips made of silicon, can carry the implications of the illusion of intelligent design about as far as we can imagine we could go -- classifying as an argument from design is the contemporary claim that the laws and constants of physics are "fine-tuned" so that the universe is able to contain life – which is commonly -- have been publicized in the popular print media, featured in television specials on PBS and BBC, and disseminated through a wide variety of popular and scholarly books, including entries from prestigious academic publishing houses such as Oxford and Cambridge University Presses -- but misleading. Furthermore, blind faith can justify anything and we have no reason to conclude that earthlike planets and sunlike stars and life itself are far too complex to have arisen by coincidence or could not have had a

purely accidental origin because **astrobiologists** have now demonstrated that captured material from a comet -- analyzed immediately after striking Earth so that effects of contamination by earthly matter are minimal-- possessed lysine, an amino acid, in the sample, suggesting that the evolution of life on Earth had only begun after accidental jump-start from space i.e., the first ingredients of life accidently came from space after Earth formed.

## LONG STANDING QUESTIONS

- What is the origin of the universe?
- What is the nature of dark matter and dark energy?
- How did the first galaxies form?
- What is the ultimate fate of the universe?
- What is the source of the cosmic microwave background radiation?
- What is the topology of the universe?
- How do black holes form and evolve?
- What is the role of inflation in the early universe?
- How did the first stars and supernovae form?
- What is the nature of the cosmic web?
- What is the nature of cosmic rays?
- What is the composition and structure of neutron stars?
- What is the ultimate source of high-energy cosmic rays?
- What is the nature of dark matter and its potential interactions with ordinary matter?
- How does dark matter affect the formation and evolution of galaxies?
- How did the large-scale structure of the universe form?
- What is the nature of the universe at high redshifts?
- What is the nature of the Hubble constant?
- How do supermassive black holes form and evolve?
- What is the nature of cosmic strings?

- What is the nature of primordial black holes?
- How do stars form and evolve?
- What is the nature of dark energy?
- How does dark energy affect the fate of the universe?
- What is the nature of the cosmological constant?
- What is the nature of the big bang singularity?
- How does the cosmic microwave background radiation constrain the early universe?
- What is the nature of the first atoms in the universe?
- What is the nature of the early universe before the era of inflation?
- What is the role of baryonic matter in the early universe?
- What is the nature of the first quasars?
- What is the nature of cosmic rays from outside the galaxy?
- What is the role of magnetic fields in the evolution of galaxies?
- What is the nature of the cosmic ray background?
- What is the nature of the cosmic neutrino background and its potential detection?
- How do gravitational waves affect the evolution of the universe?
- What is the nature of dark radiation?
- How do gravitational waves affect the formation and evolution of galaxies?
- What is the role of supermassive black holes in the evolution of galaxies?
- How did the first black holes form?
- What is the nature of cosmic voids and their evolution?
- What is the nature of cosmic rays from within the galaxy?
- What is the nature of dark energy and dark matter interactions?
- What is the role of magnetic fields in the formation and evolution of galaxies?
- What is the nature of the cosmic X-ray background?
- What is the nature of the first galaxies to form in the universe?
- How does the distribution of dark matter affect the formation and evolution of galaxies?
- What is the nature of cosmic dust?
- What is the nature of the intergalactic medium?
- What is the role of supermassive black holes in the formation of galaxies?

- What is the nature of the cosmic microwave background radiation anisotropies?
- How did the first molecules form in the universe?
- What is the nature of cosmic rays from gamma-ray bursts?
- What is the nature of cosmic ray acceleration mechanisms?
- How do gravitational lensing and dark matter affect the observations of distant galaxies?
- What is the nature of the cosmic ray energy spectrum?
- What is the role of magnetic fields in the evolution of clusters of galaxies?
- What is the nature of cosmic ray positrons?
- How did the first supernovae affect the early universe?
- What is the nature of cosmic rays from supernovae?
- What is the nature of dark matter halos?
- What is the nature of the intergalactic magnetic field?
- What is the nature of cosmic ray heavy nuclei?
- What is the nature of the first quasar outflows?
- What is the nature of the cosmic ray electron spectrum?
- What is the nature of cosmic rays from active galactic nuclei?
- What is the nature of cosmic rays from pulsars?
- What is the nature of the cosmic ray hadronic cascade?
- What is the nature of cosmic rays from starburst galaxies?
- What is the role of supermassive black holes in galaxy mergers?
- What is the nature of cosmic rays from binary systems?
- What is the nature of cosmic rays from supernova remnants?
- Why there is missing energy from a weakly interacting heavy particle? Is the direct discovery of the effects of extra dimensions or a new source of matter- antimatter asymmetry possible? An all-embracing theory of physics that unifies **quantum mechanics** **(which applies to the very small: atoms, subatomic particles and the forces between them)** and **general relativity** **(which applies to the very large: stars, galaxies and gravity, the driving force of the cosmos)** would solve the **problem of describing** everything in the universe from the big bang to subatomic particles? Our leading candidate for a **theory of everything** is known as **Mother Theory**. It grew from a merger of the

two seemingly different approaches: 11-dimensional supergravity and 10-dimensional superstring theory. Could this be the final theory of everything? What do observations of galaxies at early times tell us about how galaxies were made?

It is believed that during the first second of the universe's existence, it expanded exponentially. The two key concerns are: What caused inflation and is there hard evidence of it?

**Mapping the dark universe PROFILING THE INVISIBLE**

**Is Cosmology about to SNAP?**

**Or does it explain everything about the universe?**

Astrophysicists were shocked to discover that the universe's expansion was speeding up in 1998. This amazing discovery was attributed to "dark energy," an enigmatic component that is thought to make up more than two thirds of the universe but has not yet been clearly specified.

To answer these most challenging questions about the nature of the universe and led down open doors into new insights and findings, all the approaches must converge. Results from accelerator experiments at LHC must agree with most powerful and insightful astrophysical observations and results from sophisticated data. However, the experiments necessary to go beyond the existing knowledge of standard physics are rapidly becoming prohibitively expensive and time consuming and the macroscopic experiments are difficult to perform in the laboratory as subatomic reactions at the incredible energy scale of $10^9$ GeV -- which is far beyond the range of our largest particle accelerators and it is the biggest embarrassment in all of modern physics and if you listen closely, you can almost hear the dreams of physicists everywhere being shattered.

The weak nuclear force is 10,000,000,000,000,000,000,000,000 times greater than gravity, which the Standard Model is unable to account for.

**DECODING THE UNIVERSE SINCE 1905**

Atom → nucleus → proton → quark

So, particle physics finished……

Or is it not?

In the Grand Unified Theory, the 3 forces — strong, weak, and electromagnetic — combine as constituent parts of a single force. These forces' interaction is still a mystery.

If it is not, then what completes the particle physics?

**Flux** ← $F = \frac{L}{4\pi r^2}$ → **Luminosity**

**Surface area of the star**

**Flux** decreases as we get farther from the star

$F \propto \frac{1}{r^2}$

**Thomas Young** proposed that light was a wave. (1801). He confirmed this with a double slit experiment.

- If **r** doubles, the flux becomes one-fourth what it was.
- If **r** triples, the flux becomes one-ninth what it was.

If $m_1$ and $m_2$ = magnitudes of stars with fluxes $F_1$ and $F_2$, then:

$$m_1 - m_2 = -2.5 \log \left(\frac{F_1}{F_2}\right)$$

Logarithm to the base 10

**The lower the value of the magnitude, the brighter the star is.**

$$\frac{\text{moon's angular diameter (in arc seconds)}}{2.06 \times 10^5} = \frac{\text{moon's linear diameter}}{\text{its average distance from Earth}}$$

A prism bends a ray of light by an angle that depends on the wavelength of the light. Short wavelength (**violet light**) bends most and long wavelength (**red light**) least. Thus, white light passing through a prism is spread into its component colors.

$\mathbf{v} = \sqrt{\frac{GM}{r}}$

how fast a satellite must travel to stay in a circular orbit of radius **r** around the Earth of mass **M**.

The surface temperature of the Sun is around 5,772 K. The kinetic energy of an electron at this temperature can be calculated using the formula:

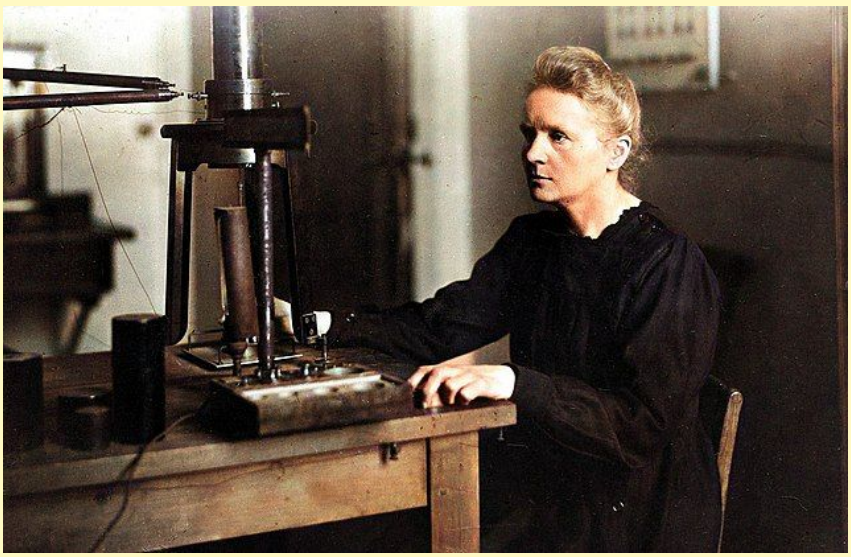
$$KE = \frac{3k_B T}{2} = \frac{3 \times 1.38 \times 10^{-23} \frac{J}{K} \times 5772\ K}{2} \approx 11.94804 \times 10^{-20}\ J$$

The kinetic energy of an electron at the surface temperature of the Sun is approximately $11.94804 \times 10^{-20}$ joules – which is very small compared to the rest mass energy of an electron.

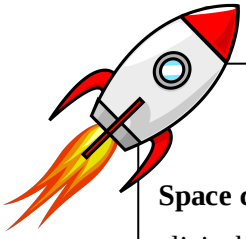
$$Flux = \sigma T^4$$

**If temperature doubles, flux increases not just twice but 16 times**

A little difference in temperature between two hot objects can produce a huge difference in the amount of energy emitted from their surfaces.



M. Sklodowska Curie



# Pro and Con: Space Colonization

**Space colonization**, or the idea of establishing permanent human settlements outside of Earth, is a topic that elicits both enthusiasm and skepticism. Here are some pros and cons of space colonization:

**Pros:**

1. **A new frontier:** Space colonization opens up new opportunities for exploration and discovery, providing humanity with a new frontier to explore and learn about.
2. **Resource availability:** Many of the resources necessary for life on Earth, such as water, minerals, and energy, are scarce and finite. Space colonization could offer access to new sources of these resources, potentially reducing pressure on the Earth's ecosystems.
3. **Spreading humanity:** By establishing settlements on other planets or moons, humanity can reduce the risk of extinction due to natural disasters, pandemics, or other catastrophes that might occur on Earth.
4. **Scientific advancement:** Space colonization can lead to technological advancements and scientific breakthroughs, as researchers work to solve the challenges of living and working in space.

**Cons:**

1. **Cost:** Space colonization is an expensive endeavor that requires significant investment, both financially and in terms of time and effort.
2. **Technological challenges:** Living in space presents numerous technological challenges, including developing sustainable habitats, finding ways to grow food, and managing waste.
3. **Ethical concerns:** Establishing settlements on other planets or moons raises ethical questions about ownership and exploitation of resources, as well as potential impacts on indigenous life.
4. **Prioritization:** Some argue that the resources and effort required for space colonization would be better spent addressing issues on Earth, such as poverty, inequality, and climate change.

In essence, **space colonization** presents both exciting opportunities and significant challenges. As humanity continues to explore the possibilities of space travel and settlement, it will be important to weigh the pros and cons carefully and to consider the potential impacts on both Earth and beyond.

## Dyson Sphere

A theoretical construct proposed by physicist **Freeman Dyson** in 1960 to be built by an advanced civilization around a star. It would serve as a vast artificial habitat with a surface area large enough to support **habitation**, while also enabling the complete capture and utilization of all the radiation emitted by the star.

## The Habitable Zone

[The Goldilocks zone]

The region around a star where conditions may be suitable for the existence of **liquid water** on the surface of a planet within this region. This zone is often considered a crucial factor for the potential habitability of a planet and the emergence of life.



$$\text{Star boundary} = \text{Sun boundary} \times \sqrt{\frac{\text{Luminosity of the Star}}{\text{Luminosity of the Sun}}}$$

The distance from the star to the boundary of its habitable zone

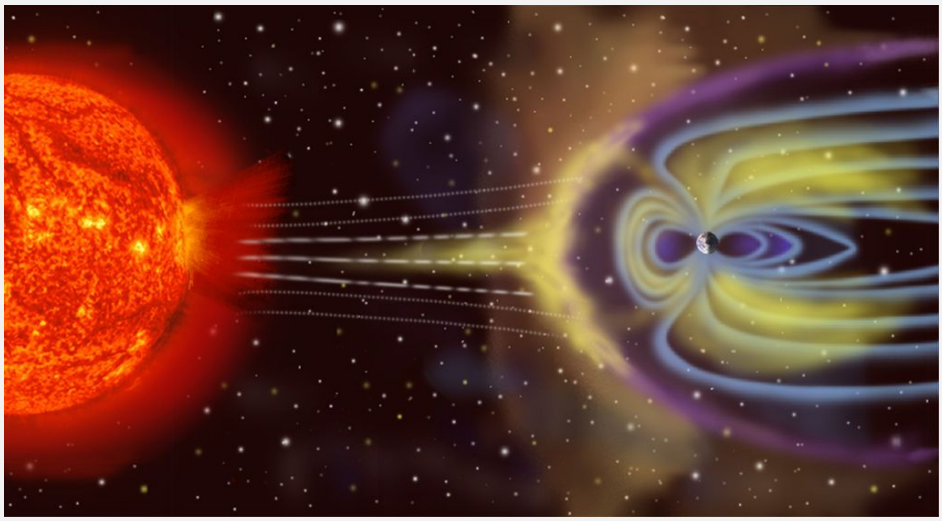
The distance from the Sun to the boundary of its habitable zone

- ✓ **If a star has a higher luminosity than the Sun**, its habitable zone will be located farther out from the star. This is because a **higher luminosity means** that the star emits more energy, resulting in a wider range of distances where the conditions are suitable for liquid water to exist on a planet's surface. The increased energy output allows planets to maintain suitable temperatures at larger distances from the star.
- ✓ **If a star has a lower luminosity than the Sun**, its habitable zone will be located closer to the star. With **lower luminosity**, the star emits less energy, leading to a narrower range of distances where the conditions can support liquid water. Planets in the habitable zone of a lower luminosity star need to be located closer to the star to receive enough energy for maintaining suitable temperatures.



## The Rare Earth Hypothesis

The emergence of complex life and intelligent civilizations in the universe is a rare occurrence. It suggests that various specific conditions, events, and factors are necessary for the development of advanced life forms, making them unlikely to exist in many other locations throughout the cosmos.



For planets to maintain surface water over extended periods, it is suggested that they require **natural protection from space weather**, such as the **magnetosphere** depicted in this artistic conception. This shielding is necessary to safeguard against harmful radiation and particles from space. Without such a protective shield, a planet's surface water may not be able to remain stable for a long time.

## The Great Filter

A concept in the field of **astrobiology** and a possible solution to the **Fermi paradox** that attempts to explain why we have not yet observed any signs of advanced **extraterrestrial civilizations**, despite the vast number of **potentially habitable planets** in the universe. The concept suggests that there may be a series of obstacles or barriers, referred to as the **"filter,"** which greatly reduces the **likelihood** of encountering detectable extraterrestrial life.

## The Galactic Habitable Zone

A **region in a galaxy** where conditions are favourable for the formation of habitable planets and the development of life.

## The metallicity of a star

The abundance of elements that are heavier than hydrogen and helium present in the star.

**In stars:**

$$X + Y + Z = 1$$

- X → mass fraction of hydrogen, which is the most abundant element in stars.
- Y → mass fraction of helium, the second most abundant element in stars.
- Z → mass fraction of all the remaining elements heavier than helium.

$$\left[\frac{\mathrm{Fe}}{\mathrm{H}}\right] = \log_{10}\left(\frac{\mathrm{N_{Fe}}}{\mathrm{N_H}}\right)_{\mathrm{star}} - \log_{10}\left(\frac{\mathrm{N_{Fe}}}{\mathrm{N_H}}\right)_{\mathrm{sun}}$$

The abundance ratio of iron compared to hydrogen in a star, relative to the Sun

A measure of the **metallicity of a star**, specifically in terms of its iron abundance.

- $N_{Fe}$ is the number of iron atoms.
- $N_H$ is the number of hydrogen atoms.
- $\left(\frac{\mathrm{N_{Fe}}}{\mathrm{N_H}}\right)_{\mathrm{star}}$ is the ratio of iron to hydrogen abundance in the star.
- $\left(\frac{\mathrm{N_{Fe}}}{\mathrm{N_H}}\right)_{\mathrm{sun}}$ is the ratio of iron to hydrogen abundance in the Sun.

A positive value of $\left[\frac{\mathrm{Fe}}{\mathrm{H}}\right]$ indicates a higher iron abundance (relative to hydrogen) compared to the Sun, while a negative value represents a lower iron abundance (relative to hydrogen) compared to the Sun.

**For example:**

- ✓ $\left[\frac{\mathrm{Fe}}{\mathrm{H}}\right]$ = +1.0 indicates that the iron abundance (relative to hydrogen) in the star is ten times higher than the iron abundance (relative to hydrogen) in the Sun.
- ✓ $\left[\frac{\mathrm{Fe}}{\mathrm{H}}\right]$ = –1.0 indicates that the iron abundance (relative to hydrogen) in the star is one-tenth **(10 times lower)** than the iron abundance (relative to hydrogen) in the Sun.

$\left[\frac{\mathrm{Fe}}{\mathrm{H}}\right]$ = 0 indicates that the iron abundance (relative to hydrogen) in the star is the same as the iron abundance (relative to hydrogen) in the Sun.

## Rare Intelligence Hypothesis

While the universe may be teeming with **simple microbial life** or even more **complex organisms**, the emergence of **intelligent civilizations** capable of technological advancement and communication is an exceedingly **rare and unlikely** occurrence.

## The Zoo Hypothesis

The advanced **extraterrestrial civilizations** may be aware of the existence of Earth and possibly even our **technological advancements** but intentionally choose not to make their presence known to us.

## Planetary protection

The policies, practices, and measures put in place to prevent the **contamination of celestial bodies**, such as planets, moons, asteroids, and comets, with biological material from Earth and to avoid the **contamination of Earth** by potential extraterrestrial life or other hazardous materials brought back from space missions.



A visualization portraying **NASA's proposed strategies** for cultivating food on the planet **Mars.**



An artistic representation showcasing the potential exploration of the **Martian surface**.

**4 hydrogen nuclei → 1 helium nuclei**

$6.690 \times 10^{-27}$ kg

$6.646 \times 10^{-27}$ kg

**mass difference**

$0.044 \times 10^{-27}$ kg

converted to energy according to $\mathbf{E= mc^2}$

$4.0 \times 10^{-12}$ J

Binding energy of the helium nuclei

**Solar nebula theory**

Planets form in the rotating disks of gas and dust around young stars

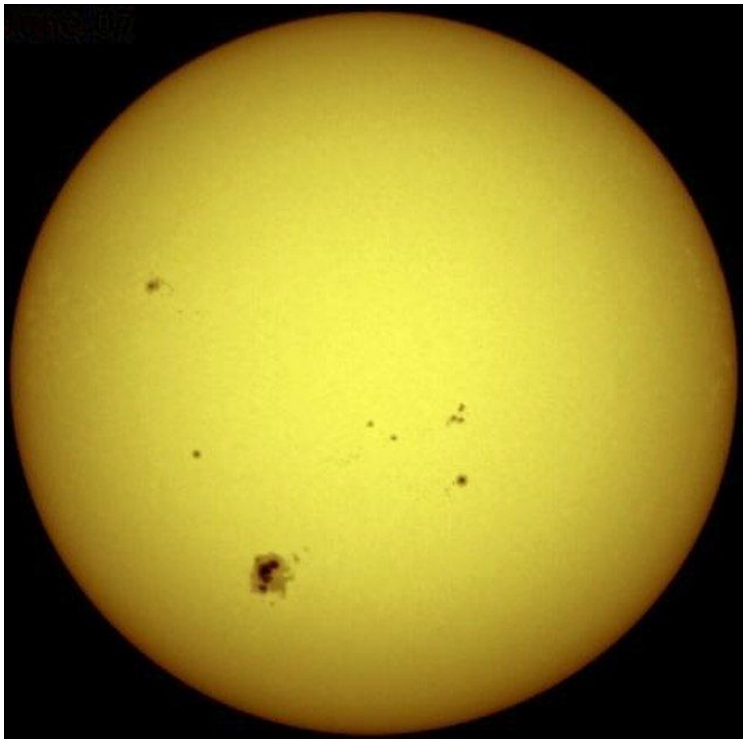
Even its thick atmosphere cannot protect **Venus** from larger meteorites.

If the radius of a star is 20 times the solar radius but only half the temperature of the sun, then:

$$\frac{L}{L_{sun}} = \frac{R^2}{R_{sun}^2} \times \frac{T^4}{T_{sun}^4} = 25$$

**The star is 25 times more luminous than the sun.**

| Sun | | |
|---|---|---|
| **Radius** | ≈ $6.9550 \times 10^8$ m | ≈ 109.2 times that of Earth |
| **Mass** | ≈ $1.98910 \times 10^{30}$ kg | ≈ 330 000 times that of Earth |
| **Mean density** | ≈ $1.408 \times 10^3$ kg/m$^3$ | ≈ 0.255 times that of Earth |
| **Escape velocity at surface** | ≈ 618 km/s | ≈ 55.2 times that of Earth |
| **Luminosity** | ≈ $3.84 \times 10^{26}$ J/s | |
| **Surface temperature** | ≈ 5772 K | |
| **Central temperature** | ≈ 15 million Kelvins | |
| **Spectral type** | G2 V | |
| **Absolute visual magnitude** | + 4.83 | |
| **Volume** | ≈ $1.41226 \times 10^{27}$ m$^3$ | ≈ 1 304 000 times that of Earth |



**The Sun showing some sunspots. The two small spots in the middle are roughly the same size as Earth.**

**Life expectancy of star** = $\frac{\text{The amount of fuel the star has}}{\text{rate of consumption of fuel}}$

The **Schwarzschild radius** depends only on the mass of the star:

$$R_s = \frac{2GM}{c^2}$$

1-solar-mass star must shrink inside its Schwarzschild radius of 2.9 km to become a black hole

10-solar-mass star must shrink inside its Schwarzschild radius of 29 km to become a black hole

| | |
|---|---|
| **Population I stars** | Metal rich stars containing 1 to 3 % metals |
| **Population II stars** | Metal poor stars containing less than 0.1% metals |

If a galaxy has a **recession velocity** of 800 km/s, and H is 70 km/s/Mpc, then the distance to the galaxy equals the velocity divided by the Hubble constant, which is

$$d = \frac{800\ \text{km/s}}{70\ \text{km/s/Mpc}} = 11.428\ \text{km}$$

**The stretching of space-time not only moves the galaxies away from each other, but it lengthens the wavelength of photons traveling through space-time.**

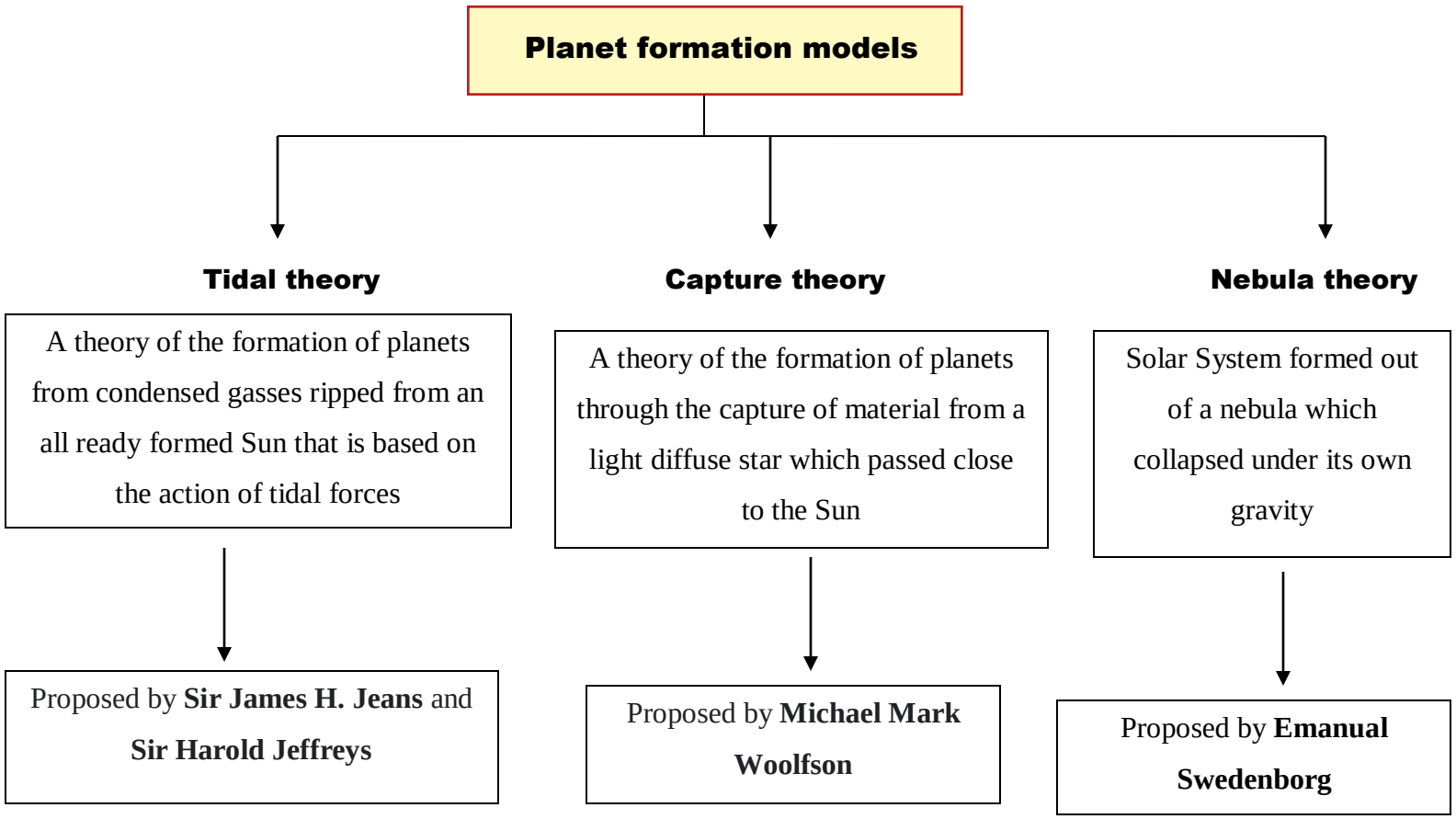
If comets were caused by the sins of mortals, they would never be absent from the sky.

**—Andreas Dudith**

| Instrument | Application |
|---|---|
| **Accelerometer** | Measures acceleration |
| **Altimeter** | Measures altitude of an aircraft |
| **Ammeter** | Measures electric current in ampere |
| **Anemometer** | Measures wind speed |
| **Barometer** | Measures atmospheric pressure |
| **Bolometer** | Measures radiant energy |
| **Caliper** | Measures distance |
| **Calorimeter** | Measures heat (in chemical reaction) |
| **Crescograph** | Measures growth in plant |
| **Dynamometer** | Measures torque |
| **Electrometer** | Measures electric charge |
| **Ellipsometer** | Measures optical refractive indices |
| **Fathometer** | Measures depth (in sea) |
| **Gravimeter** | Measures the local gravitational field of the Earth |

| | |
|---|---|
| **Galvanometer** | Measures electric current |
| **Hydrometer** | Measures specific gravity of liquid |
| **Hydrophones** | Measures sound wave under water |
| **Hygrometer** | Measures atmospheric humidity |
| **Inclinometer** | Measures angel of slope |
| **Interferometer** | Infrared light spectra |
| **Lactometer** | Measures purity of milk |
| **Magnetograph** | Measures magnetic field |
| **Manometer** | Measures pressure of gas |
| **Ohmmeter** | Measures electric resistance |
| **Odometer** | Measures distance travelled by a wheeled vehicle |
| **Photometer** | Measures intensity of light |
| **Pyrometer** | Measures temperature of a surface |
| **Radiometer** | Measures intensity or force radiation |
| **Radar** | Detects distance object, e.g. aircraft, etc. |
| **Sextant** | Measures angle between two visible objects |
| **Seismometer** | Measures motion of the ground during an earthquake |

| | |
|---|---|
| **Spectrometer** | Measures spectra (light spectrum) |
| **Theodolite** | Measures horizontal and vertical angles |
| **Thermopile** | Measures small quantities of radiant heat |
| **Thermometer** | Measures temperature |
| **Udometer** | Measures amount of rainfall |
| **Viscometer** | Measures the viscosity of fluid |
| **Voltmeter** | Measures volt |
| **Venturi meter** | Measures flow of liquid |



**Planetary migration**

Gravitational interactions between a planet and a disk of gas around a star change the **planet's** orbit, **causing** the planet to **migrate** toward or away from the star.

- **Rogue planet** → planet that does not orbit a star
- **Intergalactic star** → Star that does not gravitationally bound to any galaxy
- **Rogue extragalactic planets** → Rogue planets that reside outside the Milky Way galaxy
- **Dark nebulae** → Interstellar clouds that contain a very high concentration of dust which is dense enough to block the visible wavelengths of background light

While ordinary stars are powered by nuclear fusion reaction, hypothetical **quasi-stars** − powered by matter falling into a black hole at their center − may have existed in the early universe, shining as bright as an entire galaxy and would not have lived that long and exploded − thereby creating the materials for new generation stars and planet.

| **Huygens Wave Theory** | **Newtonian Corpuscular Theory** |
|---|---|
| Reflection | Reflection |
| Refraction | Photoelectric effect |
| Diffraction | |
| Interference | |

$$m = \frac{m_e}{\sqrt{1-\frac{v^2}{c^2}}}$$

When the velocity of the electron, v, is very small compared with light. In that case the factor $\frac{v^2}{c^2} << 1$ so that $1 - \frac{v^2}{c^2} \approx 1$ and $\sqrt{1 - \frac{v^2}{c^2}} \approx 1$, in which case the relativistic mass $m \approx m_e$!

The **cosmic microwave background** (CMB) radiation is a remnant of the **Big Bang** and is observed as a nearly uniform background of microwave radiation in the universe. The **CMB** radiation has a temperature of about **2.73 Kelvin** and is distributed uniformly in all directions. The **CMB** radiation exerts a radiation pressure on any object that absorbs it, similar to how sunlight exerts a pressure on objects in our solar system. The radiation pressure of the **CMB** is very weak, however, because the **CMB** photons have a very low energy and a long wavelength. The radiation pressure of the **CMB** is calculated using the formula:

$$P = \frac{4\sigma T^4}{3c}$$

where P is the radiation pressure, σ is the **Stefan-Boltzmann** constant, T is the temperature of the **CMB**, and c is the speed of light. Substituting the values of the constants and temperature, we get:

$$P = 4 \times 5.67 \times 10^{-8}\ W\ m^{-2}\ K^{-4} \times \frac{(2.73K)^4}{3 \times 299792458\ m/s}$$

$$P \approx 1.40072 \times 10^{-14}\ N\ m^{-2}$$

This radiation pressure is incredibly weak and has no significant effect on the motion or behavior of most objects in the universe. However, it can have a cumulative effect on very large structures, such as galaxy clusters, which can cause them to be slightly compressed or expanded along certain directions.

$$\text{Intensity} = \frac{\text{Power}}{\text{Area}}$$

$$\text{Power} = \frac{\text{Energy}}{\text{Time}}$$

$$\text{Intensity} = \frac{\text{Energy}}{\text{Time} \times \text{Area}}$$

The relationship between **intensity** and **radiation pressure** for a perfect absorber and perfect reflector is different. For a **perfect absorber**, all of the incident radiation is absorbed, so the radiation pressure on the absorbing surface is equal to the momentum of the absorbed photons per unit time and per unit area. The momentum of the absorbed photons is given by the formula:

$$p = \frac{E}{c}$$

where p is the momentum, E is the energy of the photon, and c is the speed of light. Therefore, the radiation pressure on a perfect absorber is proportional to the intensity of the radiation, according to the formula:

$$P = \frac{I}{c}$$

where P is the radiation pressure and I is the intensity of the radiation. For a perfect reflector, all of the incident radiation is reflected, so the radiation pressure on the reflecting surface is twice

the momentum of the reflected photons per unit time and per unit area. The momentum of the reflected photons is given by the formula:

$$p = \frac{2E}{c}$$

where p is the momentum, E is the energy of the photon, and c is the speed of light. Therefore, the radiation pressure on a perfect reflector is also proportional to the intensity of the radiation, according to the formula:

$$P = \frac{2I}{c}$$

where P is the radiation pressure and I is the intensity of the radiation. It should be noted that radiation pressure is independent of the incident radiation's wavelength and depends on the nature of the surface on which radiation falls.

$$P = \frac{(1+\alpha)I}{c}$$

where α is the coefficient of reflection of the surface.

- α = 1 for a completely reflecting surface
- α = 0 for a completely absorbing surface



**Albert Einstein with friends Conrad Habicht and Maurice Solovine, ca. 1903**

$$\frac{\text{Solar mass}}{\text{Proton mass}} = \frac{1.989 \times 10^{30}\ \text{kg}}{1.672 \times 10^{-27}\ \text{kg}} \approx 1.189 \times 10^{57}$$

$1.189 \times 10^{57}$ proton masses make up one solar mass.

$$\frac{\text{Solar mass}}{\text{Electron mass}} = \frac{1.989 \times 10^{30}\ \text{kg}}{9.109 \times 10^{-31}\ \text{kg}} \approx 2.183 \times 10^{60}$$

$2.183 \times 10^{60}$ electron masses make up one solar mass.

$$\frac{\text{Solar mass}}{\text{Planck mass}} = \frac{1.989 \times 10^{30}\ \text{kg}}{2.176 \times 10^{-8}\ \text{kg}} \approx 9.140 \times 10^{37}$$

$9.140 \times 10^{37}$ Planck masses make up one solar mass.

The **spin-statistics connection theorem** is a fundamental theorem in quantum field theory that relates the intrinsic angular momentum, or spin, of a particle to its statistical properties. The theorem states that particles with integer spin, such as photons or helium-4 atoms, must be bosons and exhibit **Bose-Einstein statistics**, while particles with half-integer spin, such as electrons or protons, must be fermions and exhibit **Fermi-Dirac statistics**. The **spin-statistics connection theorem** was first derived by the physicist **Wolfgang Pauli** in 1940, and it is a consequence of the assumptions of Lorentz invariance, causality, and the existence of a vacuum state. The theorem has important implications for the behavior of particles in quantum field theories, such as the **Pauli Exclusion Principle** for fermions, which states that two identical fermions cannot occupy the same quantum state simultaneously. The spin-statistics connection theorem has been verified experimentally in a variety of contexts, including the observation of **Bose-Einstein condensation** in ultracold atomic gases and the discovery of the Higgs boson at the **Large Hadron Collider**. The theorem is a key concept in **modern particle physics** and plays a central role in our understanding of the behavior of fundamental particles.

The energy density of the **CMB radiation** is proportional to the fourth power of the temperature, so any small fluctuations in the temperature of the **CMB** can have significant implications for our understanding of the early universe and the large-scale structure of the cosmos. The energy density of the **CMB** is calculated using the formula:

$$u = \frac{4\sigma T^4}{c} = 3 \times P$$

where P is the radiation pressure.

**[The black hole]** "teaches us that space can be crumpled like a piece of paper into an infinitesimal dot, that time can be extinguished like a blown-out flame, and that the laws of physics that we regard as 'sacred', as immutable, are anything but."

**–John Archibald Wheeler**

$$u = 3 \times (1.40072 \times 10^{-14}\ \text{N m}^{-2}) \approx 4.20216 \times 10^{-14}\ \text{J/m}^3$$

The energy density of the cosmic microwave background radiation is approximately $4.20216 \times 10^{-14}$ joules per cubic meter ($J/m^3$). This value is extremely small compared to typical energy densities in matter or radiation on Earth, but it is important because the **CMB radiation** is so ubiquitous in the universe and has played a key role in our understanding of the early universe and the large-scale structure of the cosmos.

**Black holes** distort the fabric of space and time around them, causing a phenomenon known as **gravitational lensing**.

**The Schwarzschild radius of a black hole**

$$R_S = \sqrt{\frac{3c^2}{8\pi G\rho}}$$

The radius of the event horizon, which is the point of no return beyond which anything, including light, is trapped and cannot escape the gravitational pull of the black hole.

The density of the black hole

As the **density of a black hole** increases, its **Schwarzschild radius** decreases.

A denser black hole will have a smaller Schwarzschild radius

If a **proton** of mass "$\mathbf{m_p}$" is released from rest in a uniform electric field of magnitude "**E**", then the magnitude of the electrical force on a proton of charge "**e**" in an electric field is given by F = e × E. **Newton's second law of motion** relates the magnitudes of the force and acceleration: F = $\mathbf{m_p}$a, so the acceleration of the proton has magnitude **a** = $\frac{eE}{m_p}$. The velocity of the proton if it travels a distance of "**x**" meter is nearly

$$eEx = \frac{m_p v^2}{2}$$

$$v = \sqrt{\frac{2eEx}{m_p}}$$

## Wien's displacement law for blackbodies:

$$\lambda_{max} T_{BH} = \frac{hc}{4.9651 k_B}$$

$$\lambda_{max} \times \frac{\hbar c^3}{8\pi G M k_B} = \frac{hc}{4.9651 k_B}$$

$$\lambda_{max} = \frac{8\pi^2}{4.9651} \times \frac{2GM}{c^2} \longrightarrow \lambda_{max} \approx 15.90\ R_S$$

The largest known black hole has a mass of about **40 billion times that of the sun** and is located in the center of the galaxy **Holmberg 15A**.

The first person to propose the idea of a black hole was **John Michell**, a British clergyman and natural philosopher, in 1783. The term "**black hole**" was coined by American physicist **John Wheeler** in 1967.

**Black holes** emit the majority of their thermal radiation at wavelengths larger than the size of their event horizon

**Plum Pudding Model of the Atom**

J.J. Thomson (1904)

The atom is a sphere of positive charge and negatively charged electrons are embedded in a positively charged atom like plums in a pudding to balance the total positive charge.

"It was quite the most incredible event that has ever happened to me in my life. It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you.

[Recalling in 1936 the discovery of the nucleus in 1909, when some alpha particles were observed instead of travelling through a very thin gold foil were seen to rebound backward, as if striking something much more massive than the particles themselves. He won the Nobel Prize in Chemistry for this discovery.]"

— **Ernest Rutherford**

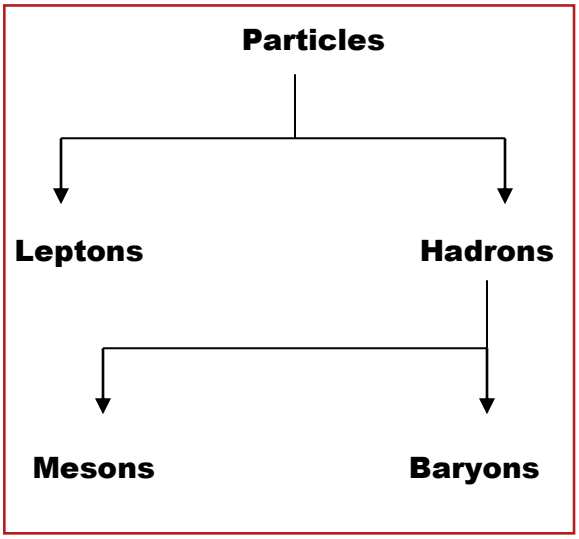
## How do we make antimatter?

Protons with energy $\frac{m_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}}$ = 26000 MeV (about 28 times their mass energy at rest [**938.272 088 16 MeV**]) collide with nuclei inside a metal cylinder. About four proton-antiproton pairs are produced in every million collisions. The antiprotons are separated from other particles using magnetic fields so that they don't come into contact with protons and self-annihilate – and are leaded to the Antiproton Decelerator, where they are slowed down from 96% to 10% of the

speed of light. They are ejected and run through beam pipes into experiments to be trapped and stored so that physicists can investigate their properties.

| | Discovered |
|---|---|
| **charm quark** | 1974@ Stanford Linear Accelerator Center, Brookhaven National Laboratory |
| **tau lepton** | 1975@ Stanford Linear Accelerator Center |
| **bottom quark** | 1977@Fermi National Accelerator Laboratory |
| **gluon** | 1978@Deutsches Elektronen-Synchrotron |
| **W and Z bosons** | 1983@CERN |
| **top quark** | 1995@ Fermi National Accelerator Laboratory |
| **tau neutrino** | 2000@ Fermi National Accelerator Laboratory |

## Major Theories and Laws in Physics

| Theory | Field |
|---|---|
| **Standard Model**<br><br>(explains how the basic building blocks of matter interact and governed by four fundamental forces)<br><br>↓<br><br>• Includes the **matter particles** (quarks and leptons), the **force carrying particles** (bosons), and the Higgs boson.<br>• It does not include gravity.<br>• According to **Standard Model**, neutrinos are massless. But recent experiments show that neutrinos possess small but non-zero mass. | **Nuclear Particle Physics**<br><br>  |

**Quantum field theory**

(classical field theory + special relativity + quantum mechanics)

**Quantum electrodynamics**

(describes the interactions of charged particles with the electromagnetic field)

↓

Maxwell 's theory of electromagnetism + Special Relativity + Quantum Mechanics

**Quantum chromodynamics**

(describes the action of the strong force)

**Electroweak theory**

(electromagnetic force + weak force)

**Effective field theory**

(describe physical systems with quantum field theory)

**Lattice field theory**

(deals with the study of lattice models of quantum field theory)

**Lattice gauge theory**

(describes gauge symmetries on a space-time lattice)

**Gauge theory**

(describes how one or more physical fields interact with matter)

**Electromagnetic and Weak forces** become equally strong at short distances of order $10^{-15}$cm

A massless particle moving in a Higgs field

↓

**A massive particle**

(Higgs field gives mass to all particles)

"Pauli asked me to calculate the cross section for pair creation of scalar particles by photons. It was only a short time after Bethe and Heitler had solved the same problem for electrons and positrons. I met Bethe in Copenhagen at a conference and asked him to tell me how he did the calculations. I also inquired how long it would take to perform this task; he answered, "It would take me three days, but you will need about three weeks." He was right, as usual; furthermore, the published cross sections were wrong by a factor of four."

**– Viki Weisskopf**

↓

Quantum mechanics + Einstein's special theory of relativity

↓

(describe subatomic particles and their associated wave fields)

**Supersymmetry**

(predicts that there is a "**superpartner**" for each elementary particle)

**Grand unification theory**

↓

(strong nuclear force + electroweak force)

↓

(describes the behavior of matter at temperatures that existed only in the first fraction of a second after the Big Bang)

**Superstring theory**

(version of string theory [**the fundamental constituents of the universe are one-dimensional "strings" rather than point-like particles**] that accounts for both fermions and bosons and incorporates Supersymmetry to model gravity)

**M-theory: The Mother of all Superstrings**

(10 spatial dimensions + 1 time dimension)

When Planck's constant → 0:
quantum electrodynamics vacuum

↓

classical vacuum

(**the vacuum of classical electromagnetism**)

We never experiment with single electrons, atoms or small molecules…In thought experiments we assume that we do. It always results in ridiculous consequences…

**(Schrödinger 1952)**

<table>
<tr><td>(unites the 5 superstrings into one theory and includes the p-branes as well)</td><td></td></tr>
<tr><td>Quantum optics<br><br>(deals with the application of quantum mechanics to phenomena involving light and its interactions with matter)</td><td>Optical physics</td></tr>
<tr><td>Quantum chemistry<br><br>(deals with the application of quantum mechanics to chemical systems)</td><td rowspan="2">Atomic and molecular physics<br><br>Moore's law:<br>Computer performance would double every 24 months or about 40% annually</td></tr>
<tr><td>Quantum information science<br><br>(deals with the analysis, processing and transmission of information using quantum mechanics principles)</td></tr>
<tr><td>BCS theory<br><br>(describes superconductivity as a microscopic effect caused by a condensation of Cooper pairs {2 electrons of opposite spin and momentum are bound together so that they have zero net spin and momentum})</td><td rowspan="4">Condensed matter physics</td></tr>
<tr><td>Theory of Bloch waves<br><br>(describes the wave function of an electron within a perfectly periodic potential)</td></tr>
<tr><td>Density functional theory<br><br>(deals with the computation of electronic structure of atoms, molecules and the condensed phases)</td></tr>
<tr><td>Fermi gas</td></tr>
</table>

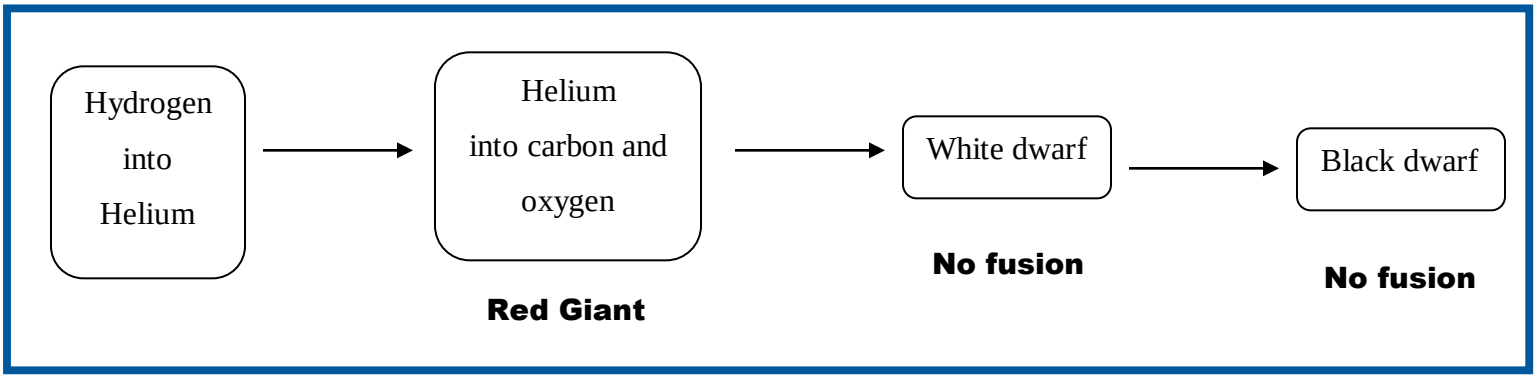
| | |
|---|---|
| (gas of **fermions** {**particles with half-integer spin**}) | |
| **Fermi liquid theory**<br><br>(describes the low temperature properties of most normal metals) | |
| **Many-body theory**<br><br>(deals with effects that manifest themselves only in systems containing large numbers of constituents) | |
| **Statistical Mechanics**<br><br>(combines the principles and procedures of statistics with the laws of both classical and quantum mechanics − particularly with respect to the field of thermodynamics) | |
| **Big Bang**<br><br>(describes the expansion of our Universe from a point of origin [**cosmic singularity**] roughly 13.8 billion years ago) | **Astrophysics** |
| **Cosmic inflation**<br><br>(deals with the exponential expansion of space in the early universe) | |
| **General relativity**<br><br>(the geometric theory of gravitation)<br>↓<br>The extension of special relativity and includes the effects of accelerating objects and their mass on space-time | |

| | |
|---|---|
| **Newton's law of universal gravitation**<br><br>(every particle attracts every other particle in the universe with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers) | |
| **Lambda-CDM** [cold dark matter] **model**<br><br>(describes the large-scale structure of the universe) | |
| **Magneto-hydrodynamics**<br><br>(deals with the study of the magnetic properties and behavior of electrically conducting fluids) | |
| **Newton's Law of universal gravitation** | **Mechanics** |
| **Newton's Laws of motion** | |
| **Ampere's Circuital Law**<br><br>(the integral of **magnetic field density** (B) along an imaginary closed path is equal to the product of current enclosed by the path and permeability of the medium) | **Current Electricity** |
| **Birch's law**<br><br>↓<br><br>establishes a linear relation between compressional wave velocity $v_P$ and density $\rho$ of rocks and minerals:<br><br>$v_P = a\bar{m} + b\rho$<br><br>where $\bar{m}$ is the mean atomic mass, a and b are constants | **Geophysics** |

<table>
<tr><td>Bell's theorem<br><br>(asserts that if certain predictions of quantum theory are correct then there exist interactions between events that are too far apart in space and too close together in time for the events to be connected even by signals moving at the speed of light)</td><td>Quantum mechanics</td></tr>
<tr><td>Beer–Lambert law<br><br>(For a given sample, the sample path length and concentration of the sample are directly proportional to the absorbance of the light)</td><td>Optics</td></tr>
<tr><td>Avogadro's law<br><br>(under the same conditions of temperature and pressure, equal volumes of different gases contain an equal number of molecules)</td><td rowspan="3">Thermodynamics</td></tr>
<tr><td>Boltzmann equation<br><br>$\text{Entropy} = k_B \times \ln W$<br><br>where W is the number of different ways in which the energy of the molecules in a system can be arranged on energy levels</td></tr>
<tr><td>Boyle's law<br><br>(the pressure and volume of a gas are inversely proportional to each other as long as the temperature and the quantity of gas are kept constant)</td></tr>
</table>

| | |
|---|---|
| **Coulomb's law**<br><br>(the electrical force between two charged particles is directly proportional to the product of the quantity of charge on the particles and inversely proportional to the square of the separation distance between the two particles) | **Electrostatics and Electrodynamics** |
| **Doppler effect**<br><br>(the increase or decrease in the frequency of sound as the source and observer move towards or away from each other) | **Sound** |
| **Special Theory of relativity**<br><br>(establishes the famous dictum that nothing — no object or signal — can travel faster than the speed of light) | **Modern Physics** |
| **Faraday's law of induction**<br><br>(the induced voltage in a circuit is proportional to the rate of change over time of the magnetic flux through that circuit) | **Electromagnetism** |
| **Gauss's law**<br><br>(the net flux of an electric field in a closed surface is directly proportional to the enclosed electric charge) | **Mathematical Physics** |
| **Pascal's law**<br><br>(the pressure applied to a fluid in a closed container is transmitted equally to all points in the fluid and act in all directions of the container) | **Fluid statics and dynamics** |
| **Planck's law**<br><br>(the electromagnetic radiation from heated bodies is not emitted as a continuous flow but is made up of discrete units | **Quantum Physics** |

| | |
|---|---|
| or quanta of energy, the size of which involve a fundamental physical constant [**Planck's constant**]) | |
| **Raman scattering**<br>(change in the wavelength of light that occurs when a light beam is deflected by molecules) | **Optics** |
| **Vlasov equation**<br>(the master equation which provides a statistical description for the collective behavior of large numbers of charged particles in mutual, long-range interaction) | **Plasma physics** |




Gauge invariance is a guiding principle in building the theory of fundamental interactions.

**–Michele Maggiore**

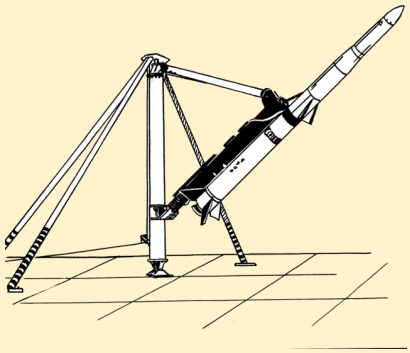
A central pillar of the Standard Model is the idea of gauge symmetry.

**– Frank Wilczek**

Clocks closer to the black hole tick more slowly.

**Time dilation becomes infinite at the event horizon**

# Acceleration of a rocket:



$$a = \frac{v_e}{m}\frac{\Delta m}{\Delta t} - g$$

- The acceleration increases as the exhaust velocity increases.
- The rocket accelerates more quickly the faster its fuel is burned.
- The acceleration increases with decreasing rocket mass.

where a is the acceleration of the rocket, $v_e$ is the exhaust velocity, m is the mass of the rocket, $\Delta m$ is the mass of the ejected gas, $\Delta t$ is the time in which the gas is ejected and g is the acceleration due to gravity.

For example, let's assume:

$$m = 3.21 \times 10^6 \text{ kg}$$

$$\frac{\Delta m}{\Delta t} = 2.56 \times 10^4 \text{ kg/s}$$

$$v_e = 5.46 \times 10^3 \text{ m/s}$$

$$a = \frac{5.46 \times 10^3 \text{ m/s}}{3.21 \times 10^6 \text{ kg}} \times 2.56 \times 10^4 \text{ kg/s} - 9.8 \text{ m/s}^2$$

$$a = 43.5439252336 \text{ m/s}^2 - 9.8 \text{ m/s}^2$$

$$a = 33.7439252336 \text{ m/s}^2$$

This means that for every second the rocket is in motion, its velocity increases by 33.7439252336 meters per second.

## Tsiolkovsky rocket equation:

$$\Delta v = v_e \ln \frac{m_0}{m_f}$$

where $\Delta v$ is the change in velocity of the rocket, $v_e$ is the exhaust velocity, $m_0$ is the initial total mass of the rocket (including propellant) at the beginning of the burn and $m_f$ is the final total mass of the rocket (after expelling the propellant).

**Let's consider an example to illustrate the equation:**

Suppose we have a rocket with an initial mass (including propellant) of 1000 kg and a final mass (after expelling the propellant) of 500 kg. The exhaust velocity is 3000 m/s. We can now calculate the $\Delta v$ using the **Tsiolkovsky rocket equation**:

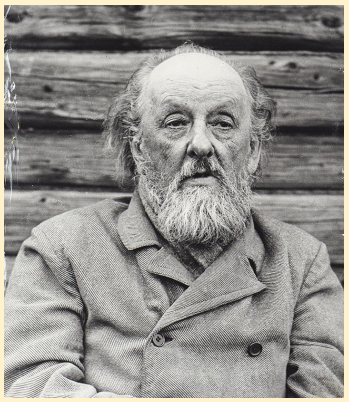
$$\Delta v = 3000 \text{ m/s} \times \ln \frac{1000 \text{ kg}}{500 \text{ kg}}$$

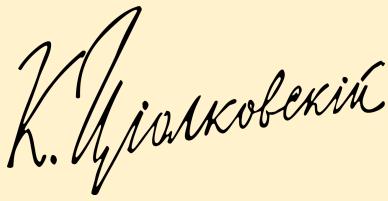
$$\Delta v = 3000 \text{ m/s} \times \ln 2$$

$$\Delta v = 2079.44 \text{ m/s}$$

It's important to note that the **Tsiolkovsky rocket equation** assumes a constant exhaust velocity throughout the burn and neglects factors such as gravity, atmospheric drag, and the changing mass of the rocket due to propellant consumption. However, it provides a valuable approximation for understanding the basic principles of rocket propulsion and $\Delta v$ calculations.







**Konstantin Tsiolkovsky** was a Russian scientist and pioneer in the field of astronautics and space exploration. **Tsiolkovsky's visionary ideas** laid the groundwork for future developments in space exploration, including the creation of the Soviet space program. His influential work continues to inspire scientists and engineers, and he is considered one of the founding **fathers of modern rocketry and spaceflight**.



Konstantin Tsiolkovsky in his working room, 1934

| Translational Motion | Rotational Motion |
|---|---|
| $\Delta x = v_0 t + \frac{1}{2} a t^2$<br><br>This equation relates the displacement ($\Delta x$) of an object to its initial velocity ($v_0$), time (t), and acceleration (a). | $\theta = \omega_0 t + \frac{1}{2} \alpha t^2$<br><br>This equation relates the angular displacement ($\theta$) of an object to its initial angular velocity ($\omega_0$), time (t), and angular acceleration ($\alpha$). |
| $v = v_0 + at$<br><br>This equation relates the final velocity (v) of an object to its initial velocity ($v_0$), acceleration (a), and time (t). | $\omega = \omega_0 + \alpha t$<br><br>This equation relates the final angular velocity ($\omega$) of an object to its initial angular velocity ($\omega_0$), angular acceleration ($\alpha$), and time (t). |
| $v^2 = v_0^2 + 2a\Delta x$<br><br>This equation relates the final velocity (v) of an object to its initial velocity ($v_0$), acceleration (a), and displacement ($\Delta x$). | $\omega^2 = \omega_0^2 + 2\alpha\theta$<br><br>This equation relates the final angular velocity ($\omega$) of an object to its initial angular velocity ($\omega_0$), angular acceleration ($\alpha$), and angular displacement ($\theta$). |

**The angular momentum (L) of the Earth can be calculated using the formula:**

$$L = I\omega = \frac{2MR^2\omega}{5}$$

where I is the moment of inertia, M is the mass, R is the radius and $\omega$ is the angular velocity. The angular velocity ($\omega$) is the rate at which the Earth rotates. It can be calculated as:

$$\omega = \frac{2\pi}{T}$$

where T is the period of rotation of the Earth, which is approximately 24 hours (86,400 seconds)

$$L = \underbrace{\frac{2 \times 5.979 \times 10^{24}\ \text{kg}\ (6.376 \times 10^{6}\ \text{m})^2}{5}}_{\frac{2MR^2}{5}} \times \underbrace{\frac{2 \times 3.14}{86{,}400\ \text{s}}}_{\frac{2\pi}{T}}$$

$$L \approx 7.07 \times 10^{33}\ \text{kg m}^2/\text{s}$$

The value of "L" is large, demonstrating that Earth possesses an immense amount of angular momentum. This is primarily due to two factors: its large moment of inertia and its relatively fast rotational speed.

## Did you Know?

When waves interact with objects much larger than their wavelength, their behaviour can be accurately described using the principles of geometric optics, and the effects of interference become negligible.

Given:

$T = 0^{o}C = 273.15\ K$

$P = 1.013 \times 10^{5}\ Pa$

$V = 1.00\ m^3$

$k_B = 1.38 \times 10^{-23}\ J/K$

**The number of molecules in a cubic meter of ideal gas at standard temperature and pressure is given by:**

$$N = \frac{PV}{k_B T} = \frac{1.013 \times 10^{5}\ \text{Pa} \times 1.00\ \text{m}^3}{1.38 \times 10^{-23} \frac{\text{J}}{\text{K}}\ 273.15\ \text{K}} \approx 2.6873 \times 10^{25}\ \text{molecules}$$

$1.00\ m^3$ of an ideal gas at STP has approximately $2.6873 \times 10^{25}$ molecules in it.

The heat energy (Q) required to change the phase of a sample from solid to liquid **(melting)** or from liquid to solid **(freezing)** is given by the equation:

$$Q = m \times L_f$$

where m is the mass of the sample and $L_f$ is the latent heat of fusion.

The heat energy (Q) required to change the phase of a sample from liquid to gas **(vaporization)** or from gas to liquid **(condensation)** is given by the equation:

$$Q = m \times L_v$$

where m is the mass of the sample and $L_v$ is the latent heat of vaporization.

The number of protons needed to make a charge of 2C is:

$$2\text{C} \times \frac{1 \text{ proton}}{1.602 \times 10^{-19} \text{ C}} \approx 1.248 \times 10^{19} \text{ protons}$$

Two coulombs of charge contains approximately $1.248 \times 10^{19}$ protons.

The wavelength in a medium of refractive index **n** is related to the wavelength in vacuum **λ** by the following equation:

$$\lambda_n = \frac{\lambda}{n}$$

where $\lambda_n$ is the wavelength in the medium. Let's consider an example where we have an electromagnetic wave propagating from vacuum (air) into a medium with a refractive index of 1.5. We'll assume the wavelength in vacuum ($\lambda$) is 450 nm.

$$\lambda_n = \frac{450 \text{ nm}}{1.5} = 300 \text{ nm}$$

So, in this example, when the wave enters the medium with a **refractive index** of 1.5, its wavelength reduces to approximately 300 nm. This means that the electromagnetic wave becomes more compressed in the medium compared to its wavelength in vacuum.

The **Doppler Effect** is the change in frequency or wavelength of a wave as observed by an observer moving relative to the source of the wave. The equation for the **Doppler Effect** depends on whether the observer is moving toward or away from the source. If the observer is moving toward the source and if the source is moving away from the observer, the relationship between observed frequency ($\upsilon$) and emitted frequency ($\upsilon_0$) is given by:

$$\upsilon = \upsilon_0 \frac{v + v_0}{v + v_s}$$

If the observer is moving away from the source and if the source is moving towards the observer, the relationship between observed frequency ($\upsilon$) and emitted frequency ($\upsilon_0$) is given by:

$$\upsilon = \upsilon_0 \frac{v - v_0}{v - v_s}$$

- $v$ is the speed of sound or light waves
- $v_0$ is the velocity of the observer,
- $v_s$ is the velocity of the source.

Let's say a car with a siren is moving at a velocity of 20 m/s towards a stationary observer. The siren emits a sound wave with a frequency of 1000 Hz. The speed of sound in air is approximately 343 m/s.

Given:

$\upsilon_0 = 1000$ Hz

$v = 343$ m/s

$v_0 = 0$ m/s (as the observer is stationary)

$v_s = 20$ m/s

The observed frequency:

$$\upsilon = \upsilon_0 \frac{v}{v - v_s} = 1000\ \text{Hz} \times \frac{343\ \text{m/s}}{343\ \text{m/s} - 20\ \text{m/s}} = 1061.91\ \text{Hz}$$

Therefore, the stationary observer perceives the sound frequency of the siren as 1061.91 Hz, which is higher than the emitted frequency of 1000 Hz due to the **Doppler Effect** caused by the relative motion between the source **(car)** and the stationary observer.

The energy of a **quantum mechanical oscillator** having a frequency υ is given by:

$$E = \left(n + \frac{1}{2}\right) h\upsilon$$

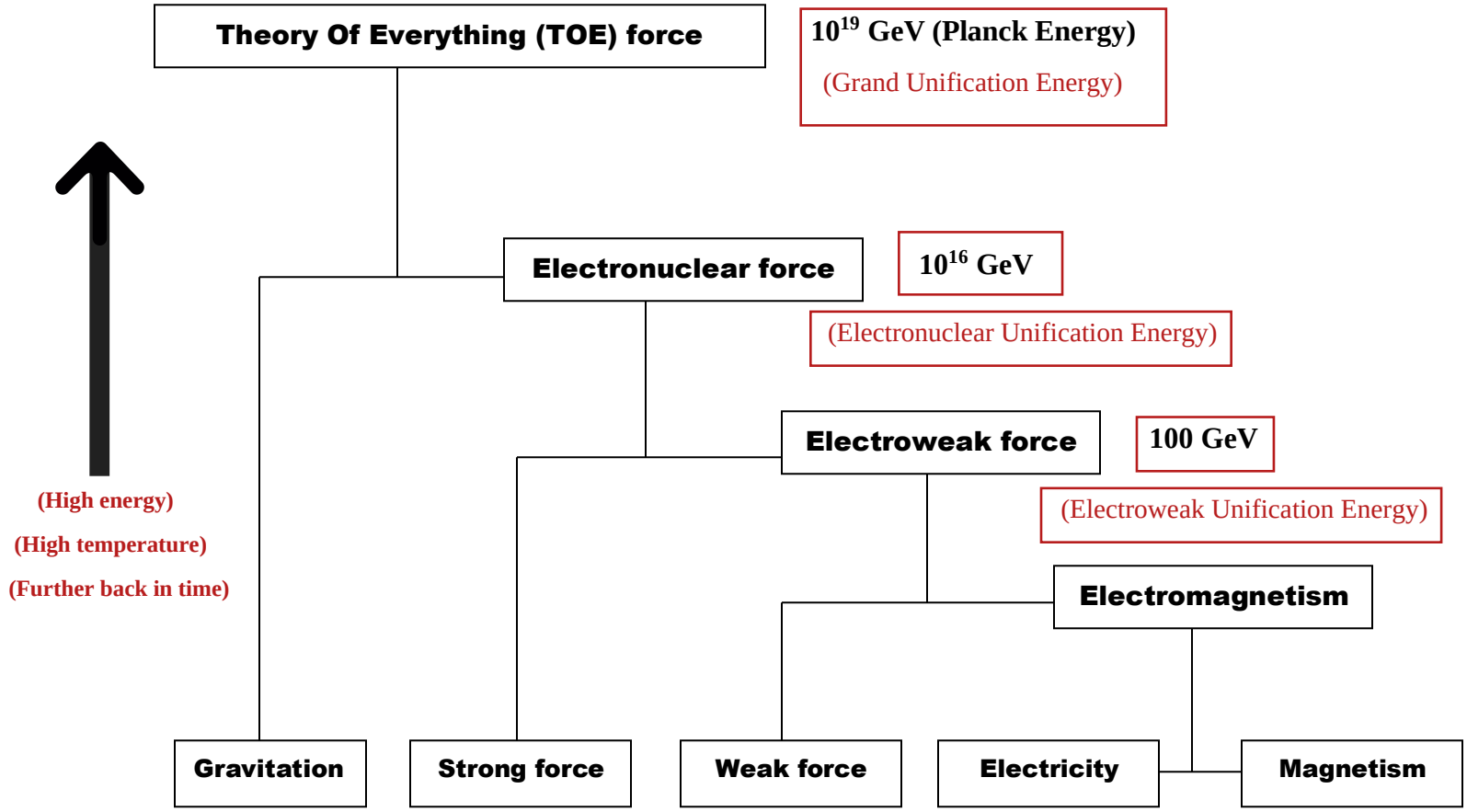
where h is the Planck's constant and n is any nonnegative integer (0, 1, 2, 3, …). The **quantum mechanical oscillator** has an energy for n = 0 of $E_0 = \frac{1}{2} h\upsilon_0$. This is known as the **Zero Point Energy of the oscillator**.

The lowest possible energy that a quantum mechanical oscillator can have



Being the first to recognise that energy can be quantized

**Max Planck** in 1918, the year when his contributions to quantum theory earned him the Nobel Prize in Physics.




| Special Relativity | General Relativity |
|---|---|
| Invariance of Physical Laws<br>Invariance of the speed of light | Principle of Equivalence |
| **Applications:**<br>• Relativity of Simultaneity<br>• Time Dilation<br>• Length Contraction | **Applications:**<br>• Bending of light<br>• Modification of time by gravitational fields |

## Self-Replicating Probes

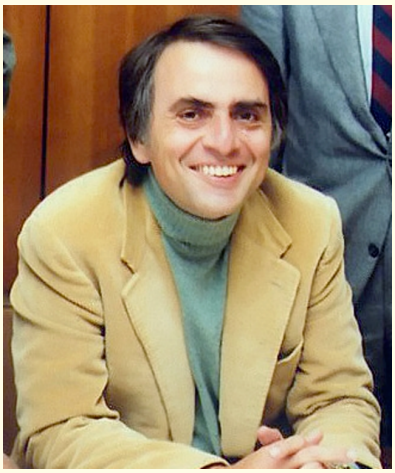
[von Neumann probes]

This conception **(named after Hungarian American mathematician and physicist John von Neumann)** involves sending out a **probe** or **spacecraft** capable of building copies of itself using materials and energy found in its environment. These replicated probes, in turn, can create additional copies, leading to an exponential growth in the number of probes exploring the universe.

## The Coleman–Sagan equation

$$P_c = N_0 \times R \times P_s \times P_t \times P_R \times P_g$$

- $P_c$ → The probability of contaminating another planetary body by microorganisms
- $N_0$ → The initial number of microorganisms that could be present on or in a spacecraft.
- $R$ → Microbial Reduction due to conditions on spacecraft before and after launch.
- $P_s$ → The Probability that microorganisms on the spacecraft reach planet surface.
- $P_t$ → The Probability that spacecraft hits (or lands) on the planet.
- $P_R$ → The Probability that microorganisms will be released from spacecraft after landing.
- $P_g$ → The probability of the microbial growth on the planet.



"Across the sea of space, the stars are other suns."

**– Carl Sagan, Cosmos**

✓ The **Seager equation**, named after the astrophysicist **Sara Seager**, is an equation used in the search for exoplanets (planets outside our solar system) that may support life.

A **biosignature gas** is a gas that is produced by living organisms through metabolic activity and accumulates in an atmosphere to detectable levels. Biosignature gases can serve as potential indicators of the presence of life on a planet or moon.

The **Seager equation** is expressed as:

$$N = N_* \times F_Q \times F_{HZ} \times F_O \times F_L \times F_S$$

- $N$ ⟶ The number of planets with detectable signs of life.
- $N_*$ ⟶ The number of stars observed.
- $F_Q$ ⟶ The fraction of stars that have lower levels of stellar activity.
- $F_{HZ}$ ⟶ The fraction of stars with rocky planets in the habitable zone.
- $F_O$ ⟶ The fraction of those planets that can be observed.
- $F_L$ ⟶ The fraction of those planets that have life.
- $F_S$ ⟶ The fraction of planets with life where the life produces a detectable **biosignature gas**.

## Aestivation hypothesis

A proposed solution to the **Fermi Paradox**, which raises the question of why we have not yet detected any signs of advanced extraterrestrial civilizations.

**Advanced alien civilizations** might have made the choice to enter a **state of dormancy** until the universe cools down, with the goal of maximizing their resource utilization for future exploration. By going inactive during periods of **unfavourable cosmic conditions**, these civilizations would conserve energy and resources, enabling them to allocate those reserves towards extensive exploration once the universe becomes more suitable for their activities.





## Landauer's principle

The minimum energy required to erase one bit of information from a system is proportional to the temperature at which the system is operating.

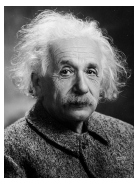
**Mathematically expressed as:**

$$E \geq k_B T \ln(2)$$

where $k_B$ is the Boltzmann constant. **At room temperature:** $E \geq 2.9 \times 10^{-21}$ J.

At room temperature, which is typically around 300 Kelvin, the **Landauer limit** corresponds to a minimum energy requirement equal to or greater than $2.9 \times 10^{-21}$ Joules to erase one bit of information. This value represents the energy threshold set by **Landauer's principle** for the efficient erasure of information at room temperature.





Classical Newtonian Mechanics
Classical Maxwellian Electrodynamics
Special Relativity
Quantum Mechanics
Relativistic Mechanics
Relativistic Quantum Mechanics
Relativistic Electrodynamics
(Relativistic EM Field Theory)
Quantum Electrodynamics
(Relativistic Quantum EM Field Theory)
Relativistic Quantum Field Theory
Newton
Optics
Spectrum of elements
Gravitation
General theory of relativity
Einstein
Special theory of relativity
Expanding universe

$$\frac{\text{Planck charge}}{\text{electron charge}} = \frac{1.875546 \times 10^{-18} \text{C}}{1.602 \times 10^{-19}\ \text{C}} \approx 11.78$$

**11.78 electron charges make up one Planck charge**

$$\frac{\text{Mass of the sun}}{\text{Mass of the earth}} = \frac{1.98 \times 10^{30} \text{kg}}{5.97 \times 10^{24}\ \text{kg}} \approx 331658.2$$

**331658.2 Earth masses** make up one Solar mass

$$\frac{\text{Mass of the sun}}{\text{Mass of the moon}} = \frac{1.98 \times 10^{30} \text{kg}}{7.34 \times 10^{22}\ \text{kg}} \approx 26975476.8$$

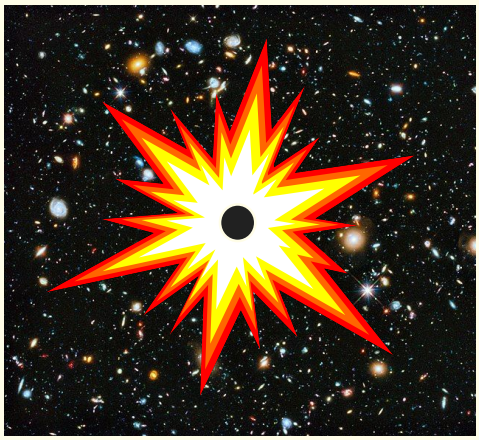
**26975476.8 Lunar masses** make up one Solar mass

The **Sun** can be approximated as a blackbody radiator with a surface temperature of about 5,772 Kelvin. Using Wien's Law, we can calculate the peak wavelength of the radiation emitted by the Sun as follows:

$$\lambda_{peak} = \frac{\text{Wien's constant}}{T} = \frac{2.897 \times 10^{-3}\ \text{mK}}{5772\ \text{K}} \approx 5.0190575 \times 10^{-7}\ \text{m}$$

The peak wavelength of the electromagnetic radiation emitted by the Sun is approximately $5.0190575 \times 10^{-7}$ meters, which corresponds to the green region of the visible spectrum.

# Evolution of the Universe:



| Epoch | Main event |
|---|---|
| Planck | No current theory of physics; quantum gravity |
| GUT (Grand Unified Theory) | Strong, weak and electromagnetic forces united |
| Quark | Strong force frozen out. Heavy and light particles all in thermal equilibrium. Electroweak force freezes out at $10^{15}$K. |
| Lepton | Only low-mass particles still in thermal equilibrium; neutrinos decouple at $10^{10}$K. |
| Nuclear | Deuterium and helium formed by fusion of protons and neutrons during first 1000 seconds. |
| Atomic | Matter begins to dominate; atoms form; electromagnetic radiation decouples. |
| Galactic | Large-scale structure forms; first stars and quasars shine; galaxies form and grow. |
| Stellar | Galaxies merge and evolve; star formation peaks. Dark energy begins to dominate. |

**Extends into the Dark Energy Era**

Planck length = $\sqrt{\frac{\hbar G}{c^3}}$

- Gravitational limit of quantum theory
- Quantum limit of general relativity

Planck mass = $\sqrt{\frac{\hbar c}{G}}$

- Upper limit on the mass of elementary particles
- Lower limit on the mass of a black hole

Planck temperature = $\frac{m_{Planck} c^2}{k_B}$ — Upper limit of temperature

Planck density = $\frac{m_{Planck}}{L_{Planck}^3}$ — Limiting density of matter

**Laser**

↓

Light Amplification through the Stimulated Emission of Radiation

**Quantum mechanics** is very respectable. But an inner voice tells me that it is not yet the real thing. The theory says a lot, but hardly brings us any closer to the mystery of the old one. In any case, I am convinced that He is not rolling dice.

**Albert Einstein Letter to Max Born, 4 December 1926**



Albert Einstein

In the Sun, the nuclear fusion reaction converts hydrogen nuclei into helium nuclei. The fusion reaction is called the **hydrogen – hydrogen cycle** or proton – proton cycle.

proton + proton → deuterium + positron + electron neutrino **(a weak nuclear reaction)**

deuterium + proton → $^{3}He$ + energy **(a strong nuclear reaction)**

$^{3}He + {}^{3}He \rightarrow {}^{4}He$ + 2 protons + energy

The energy released by this process powers the Sun and other stars and is essential for the existence of life on Earth.

**If the masses, lifetimes and magnetic moments of matter and antimatter particles would differ, the CPT symmetry would be violated.**

About $10^{16}$ neutrinos pass through our body every second.

| | |
|---|---|
| **quantum electrodynamics** | describe the electromagnetic interaction |
| **quantum chromodynamics** | describe the strong nuclear interaction |
| **quantum flavordynamics** | describe the weak nuclear interaction |
| **Quantum field theory** | describe the particle transformations |

- the electromagnetic interaction
- the strong nuclear interaction
- the weak nuclear interaction

→ Involve the Exchange of virtual bosons

**In these interactions:** energy, momentum, angular momentum, electric charge, colour charge, **CPT parity**, lepton number and baryon number are conserved.

Eskimo nebula (NGC 2392)



**Electron-proton mass ratio**

↓

Much smaller → No solids

- **vector bosons** — the photon, W and Z bosons, gluons
- **Higgs boson** — the only known fundamental scalar boson
- **graviton** — a hypothetical tensor boson

**Baryon number**

↓

Much higher → No solar system

**Vacuum energy density**

↓

Change by $10^{-55}$ → No flatness

- (3 + 1) dimensions → different → No atoms, no planetary systems
- **No Permutation symmetry** → No matter
- No Lorentz symmetry → No communication possible
- **Different U(1) symmetry** → No Huygens principle
- Different SU (2) symmetry → No radioactivity, no Sun, no life
- Different SU (3) symmetry → No stable quarks and nuclei

**Oort cloud object number**

↓

Smaller → No comets, no irregular asteroids

**Initial cosmic speed**

↓

**Increase by** 0.1% → 1000 times faster cosmic expansion

| | |
|---|---|
| **6 to 8 Generations of Particles** | Only helium in nature |
| **Greater than 8 Generations of Particles** | No asymptotic freedom and confinement |

**Neutron-proton mass difference**

↓

Smaller than electron mass

↓

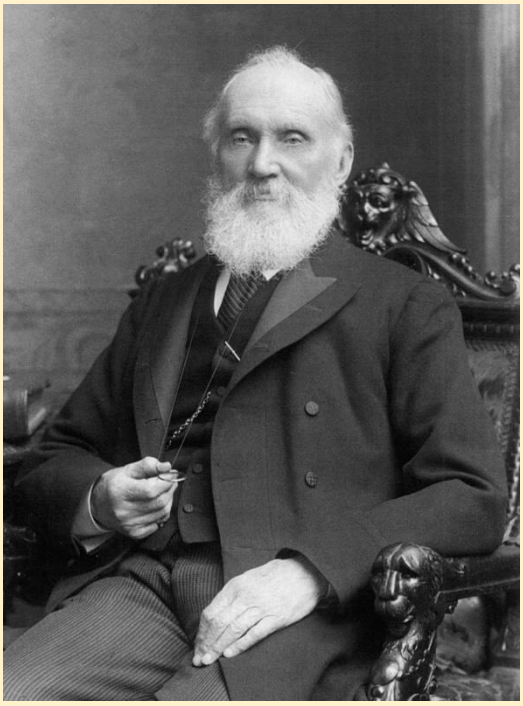
Protons would capture electrons, no hydrogen atoms

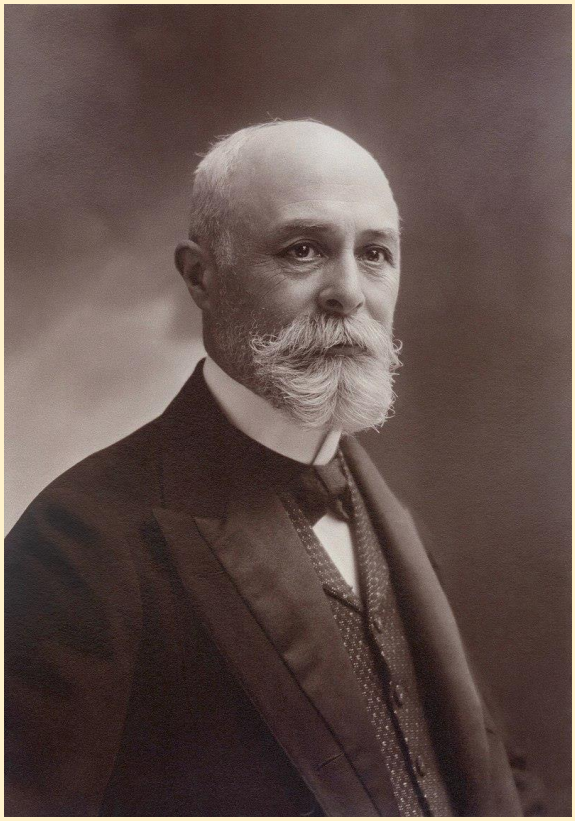
**Galaxy centre distance**

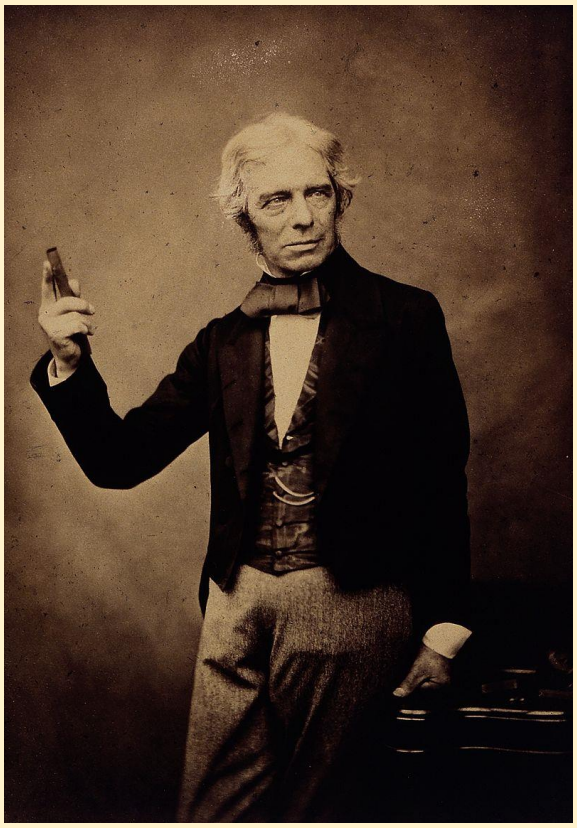
↓

Smaller → Irregular planet motion

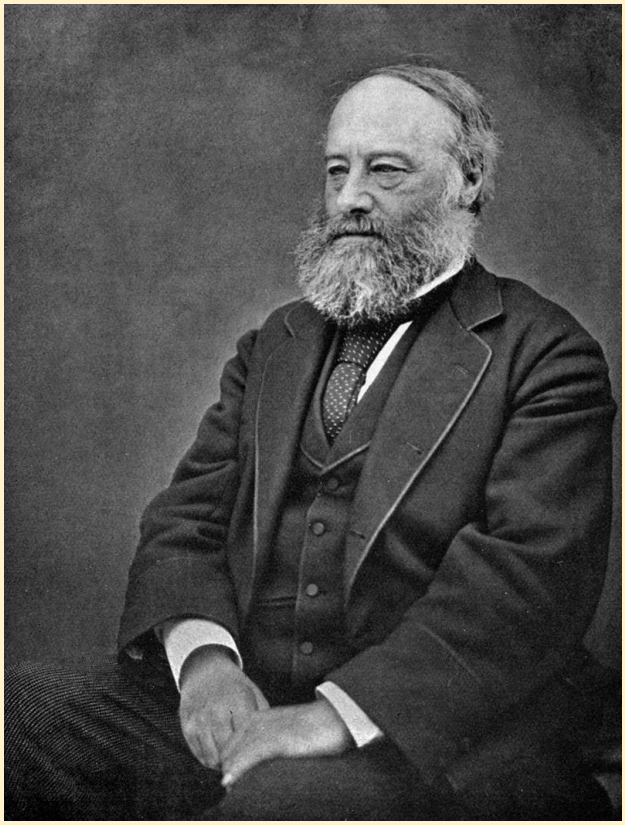
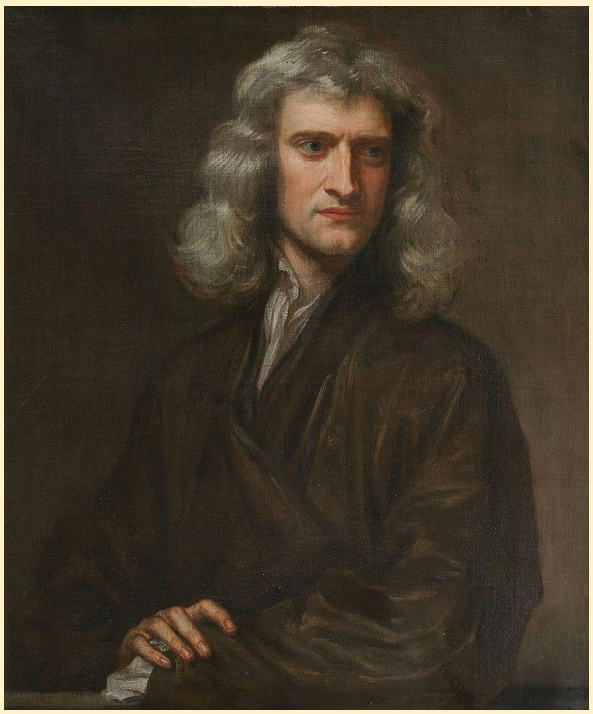
# Scientific Units Named After Inventors

| Scientist | Unit | Measures |
| --- | --- | --- |
|  <br>**André-Marie Ampère** | **ampere (A)**<br><br>Named after **André-Marie Ampère**, a French physicist who made important contributions to the ***study*** of electromagnetism. | Electric current |
|  <br>**Lord Kelvin** | **kelvin (K)**<br><br>Named after William **Thomson, 1st Baron Kelvin**, a Scottish physicist who developed the Kelvin temperature scale. | Thermodynamic temperature |

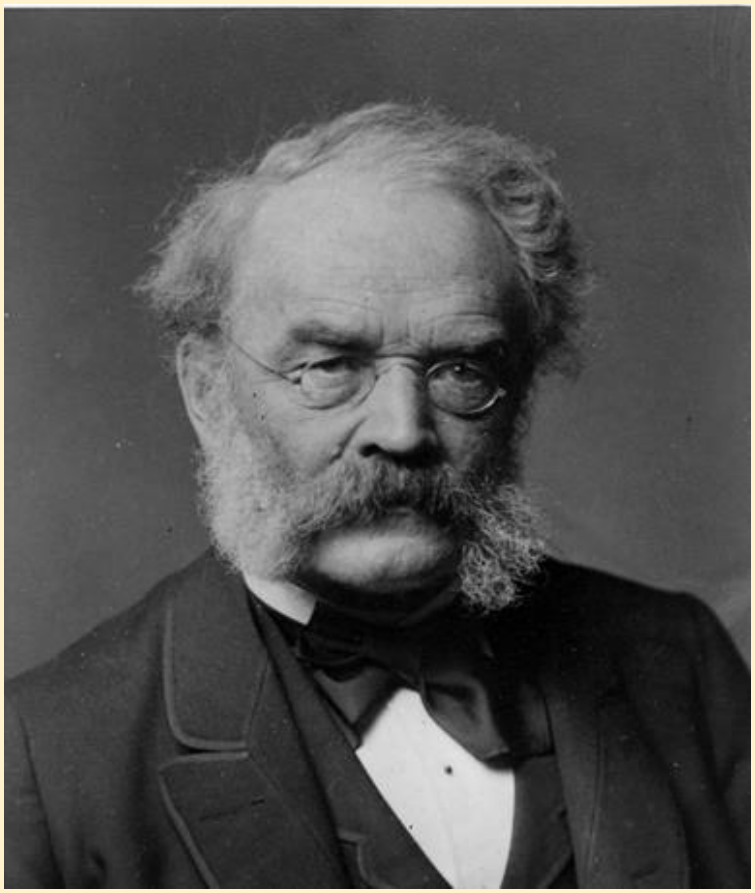
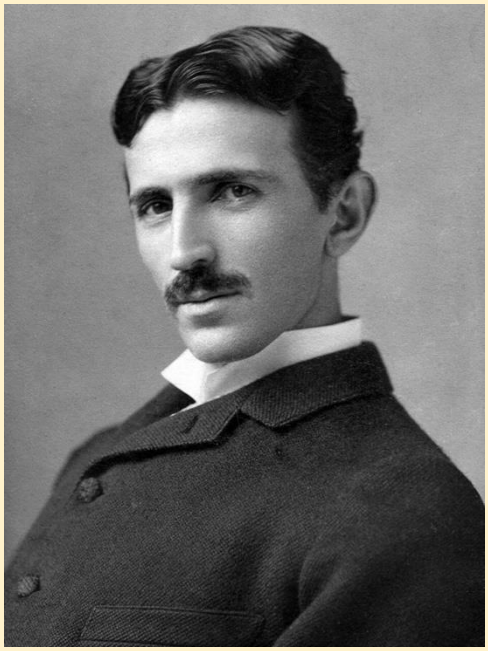
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|---|---|---|
|  <br>**Antoine Henri Becquerel** | **becquerel (Bq)**<br><br>Named after **Henri Becquerel**, a French physicist who discovered radioactivity. | Radioactivity |
|  <br>**Anders Celsius** | **degree Celsius (°C)**<br><br>Named after **Anders Celsius**, a Swedish astronomer who invented the Celsius temperature scale. | Temperature |

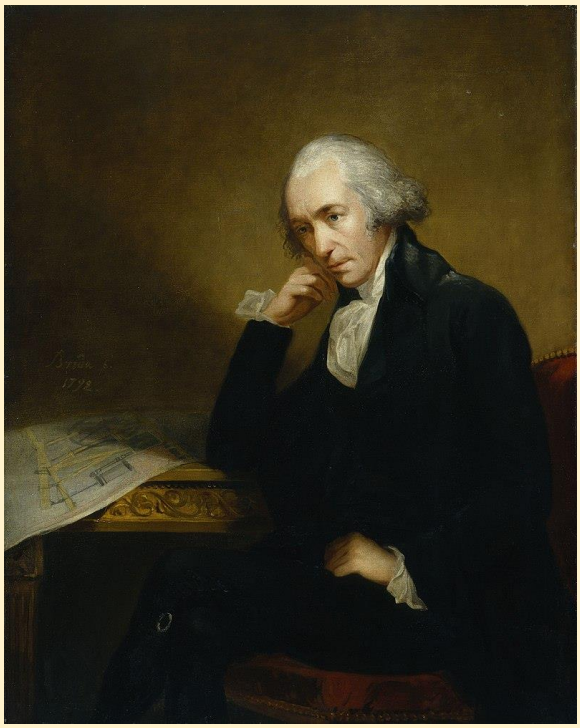
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|---|---|---|
|  <br>**Charles-Augustin de Coulomb** | **coulomb (C)**<br><br>Named after **Charles-Augustin de Coulomb**, a French physicist who made important contributions to the study of electrostatics. | Electric charge |
|  <br>**Michael Faraday** | **farad (F)**<br><br>Named after **Michael Faraday**, an English scientist who made important contributions to the study of electromagnetism and electrochemistry. | Capacitance |

| | | |
|---|---|---|
|  <br>**Joseph Henry** | **henry (H)**<br><br>Named after **Joseph Henry**, an American scientist who made important contributions to the study of electromagnetism. | Inductance |
|  <br>**Heinrich Rudolf Hertz** | **hertz (Hz)**<br><br>Named after **Heinrich Hertz**, a German physicist who was the first to demonstrate the existence of electromagnetic waves. | Frequency |

| | | |
|---|---|---|
|  <br>**James Prescott Joule** | **joule (J)**<br><br>Named after **James Prescott Joule**, an English physicist who made important contributions to the study of thermodynamics. | Energy, work, heat |
|  <br>**Sir Isaac Newton** | **newton (N)**<br><br>Named after **Sir Isaac Newton**, an English mathematician, physicist, and astronomer who formulated the laws of motion and universal gravitation. | Force |

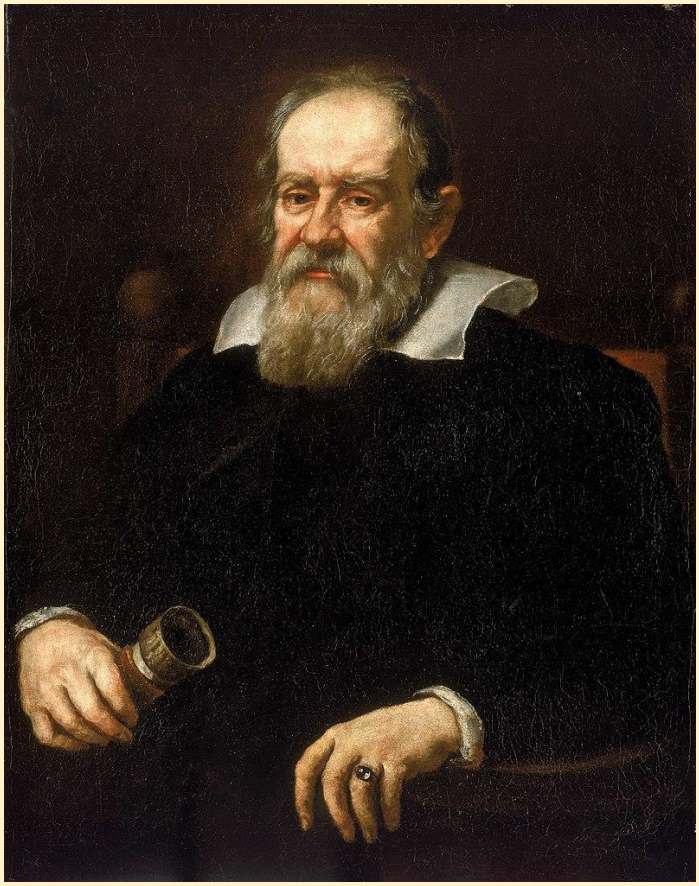
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|---|---|---|
|  <br>**Georg Simon Ohm** | **ohm (Ω)**<br><br>Named after **Georg Simon Ohm**, a German physicist who formulated Ohm's law. | Electrical resistance |
|  <br>**Blaise Pascal** | **pascal (Pa)**<br><br>Named after **Blaise Pascal**, a French mathematician, physicist, and philosopher who made important contributions to the study of fluids and pressure. | Pressure |

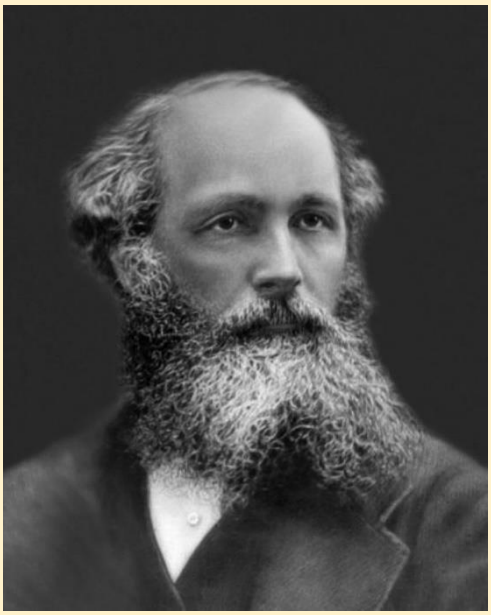
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|---|---|---|
|  <br>**Werner von Siemens** | **siemens (S)**<br><br>Named after **Werner von Siemens**, a German inventor and electrical engineer who made important contributions to the development of electrical engineering. | Electrical conductance |
|  <br>**Nikola Tesla** | **tesla (T)**<br><br>Named after **Nikola Tesla**, a Serbian-American inventor who made important contributions to the development of the alternating current (AC) electrical system. | Magnetic flux density |

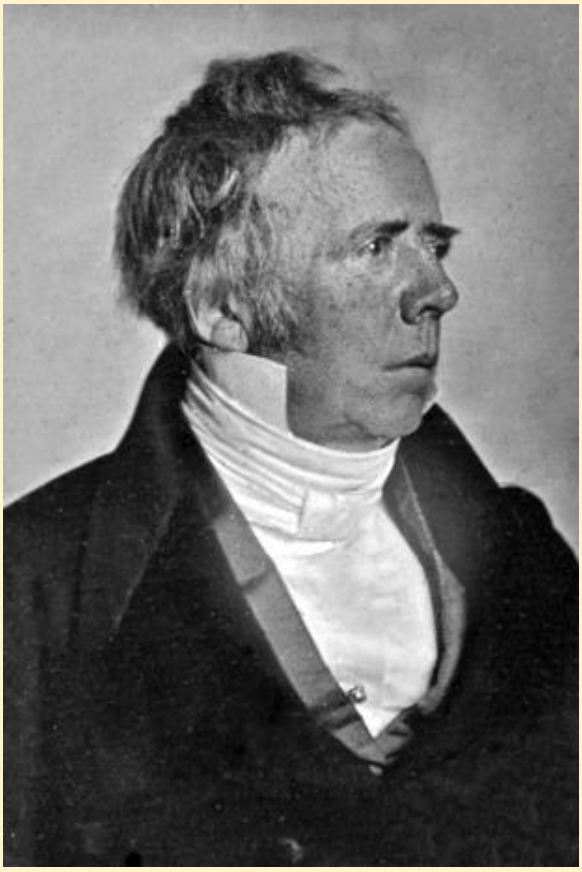
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|  <br>**Alessandro Volta** | **volt (V)**<br><br>Named after **Alessandro Volta**, an Italian physicist who invented the first battery. | Electric potential and electromotive force |
|  <br>**James Watt** | **watt (W)**<br><br>Named after **James Watt**, a Scottish inventor, mechanical engineer, and chemist who invented the steam engine. | Power and radiant flux |

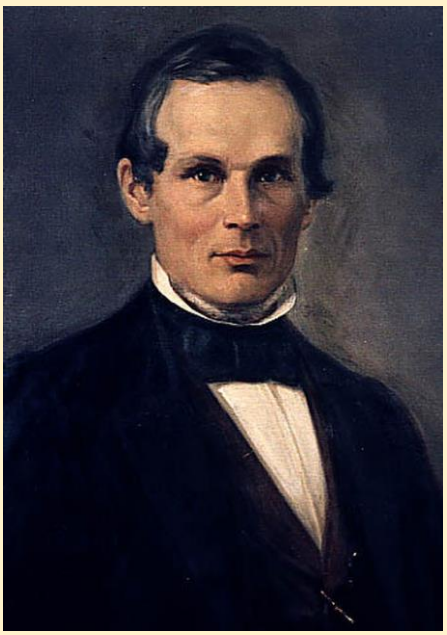
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|---|---|---|
|  <br>**Wilhelm Eduard Weber** | **weber (Wb)**<br><br>Named after **Wilhelm Eduard Weber**, a German physicist who made important contributions to the study of electromagnetism. | magnetic flux |
|  <br>**Jean-Baptiste Biot** | **biot (Bi)**<br><br>Named after **Jean-Baptiste Biot**, a French physicist who made important contributions to the study of optics and magnetism. | Electric current |

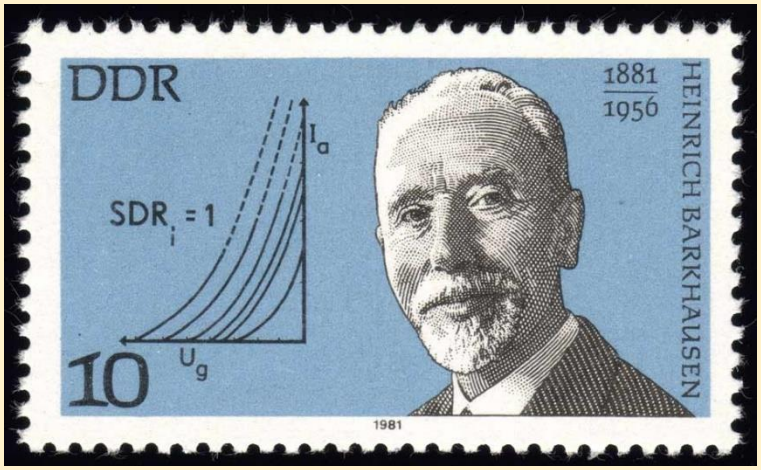
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|  <br>**Peter Debye** | **debye (D)**<br><br>Named after **Peter Debye**, a Dutch physical chemist who made important contributions to the study of molecular structure and chemical bonding. | Electric dipole moment |
|  <br>**Loránd Eötvös** | **eotvos (E)**<br><br>Named after **Loránd Eötvös**, a Hungarian physicist who made important contributions to the study of gravitation and thermodynamics. | Gravitational gradient |

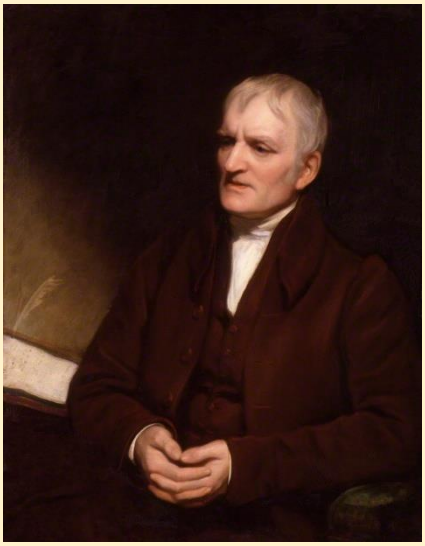
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|---|---|---|
|  <br>**Galileo Galilei** | **galileo (Gal)**<br><br>Named after **Galileo Galilei**, an Italian physicist and astronomer who made important contributions to the study of motion and mechanics. | Acceleration |
|  <br>**Carl Friedrich Gauss** | **gauss**<br>**(G or Gs)**<br><br>Named after **Carl Friedrich Gauss**, a German mathematician and physicist who made important contributions to many fields, including electromagnetism. | Magnetic flux density |

| | | |
|---|---|---|
|  <br>**William Gilbert** | **gilbert (Gb)**<br><br>Named after **William Gilbert**, an English physician and physicist who is credited with being the founder of the science of magnetism. | Magnetomotive force |
|  <br>**James Clerk Maxwell** | **maxwell (Mx)**<br><br>Named after **James Clerk Maxwell**, a Scottish physicist and mathematician who made important contributions to the study of electromagnetism. | Magnetic flux |

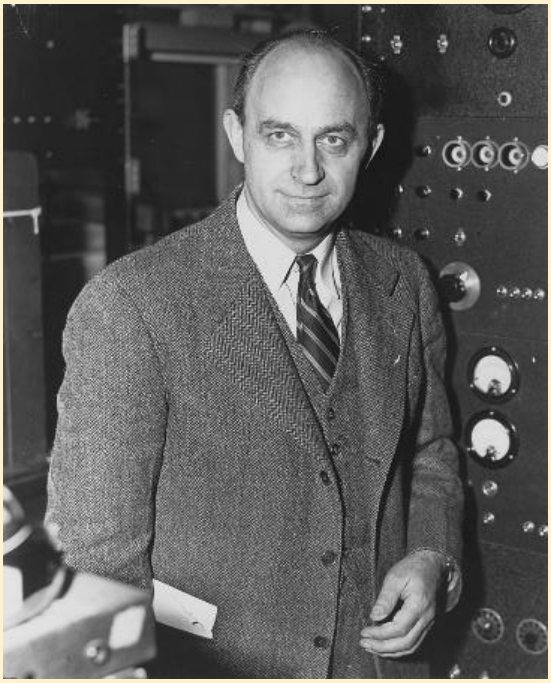
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|  <br>**Hans Christian Ørsted** | **oersted (Oe)**<br><br>Named after **Hans Christian Ørsted**, a Danish physicist who discovered the relationship between electric currents and magnetic fields. | Magnetic field strength |
|  <br>**Jean Léonard Marie Poiseuille** | **poise (P)**<br><br>Named after **Jean Louis Marie Poiseuille**, a French physician and physiologist who made important contributions to the study of fluid mechanics. | Dynamic viscosity |

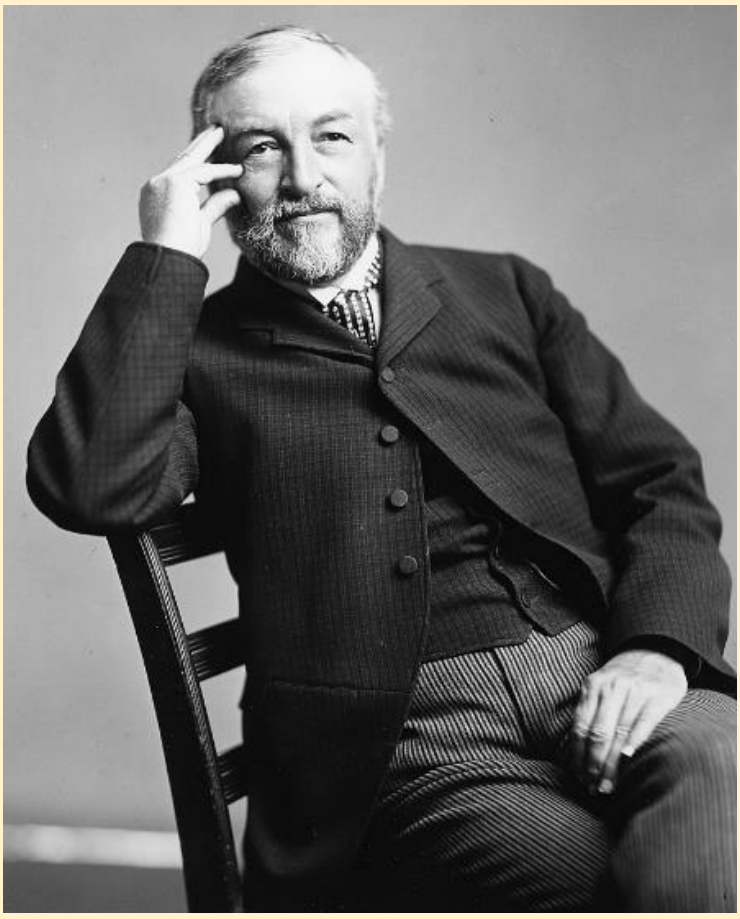
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|---|---|---|
|  <br>**George Gabriel Stokes** | **stokes**<br>**(S or St)**<br><br>Named after **Sir George Gabriel Stokes**, an Irish mathematician and physicist who made important contributions to the study of fluid dynamics. | Kinematic viscosity |
|  <br>**Anders Jonas Ångström** | **ångström (Å)**<br><br>Named after **Anders Jonas Angstrom**, a Swedish physicist and astronomer who made important contributions to the study of spectroscopy. | Distance |

| | | |
|---|---|---|
|  <br>**Heinrich Barkhausen** | **Bark scale**<br><br>Named after **Heinrich Barkhausen**, a German physicist who made important contributions to the study of electromagnetic oscillations. | Psychoacoustical scale |
|  <br>**Thomas Hunt Morgan** | **centimorgan (cM)**<br><br>Named after **Thomas Hunt Morgan**, an American geneticist who made important contributions to the study of genetics and is credited with being the father of modern genetics. | Recombination frequency |

| | | |
|---|---|---|
|  <br>**Marie Curie and Pierre Curie** | **curie (Ci)**<br><br>Named after **Marie and Pierre Curie**, the French physicists and chemists who discovered the radioactive elements radium and polonium. | Radioactivity |
|  <br>**John Dalton** | **dalton (Da)**<br><br>Named after **John Dalton**, the British chemist and physicist who developed the atomic theory of matter. | Atomic mass |

| | | |
|---|---|---|
|  <br>**Henry Darcy** | **darcy (D)**<br><br>Named after **Henry Darcy**, a French engineer who made important contributions to the study of fluid mechanics. | Permeability |
| **Gordon Dobson** | **Dobson unit (DU)**<br><br>Named after **Gordon Dobson**, a British physicist who developed the **Dobson spectrophotometer**, an instrument used to measure the concentration of atmospheric ozone. | Atmospheric ozone |
|  <br>**Daniel Gabriel Fahrenheit** | **degree Fahrenheit (°F)**<br><br>Named after the German physicist **Daniel Gabriel Fahrenheit**, who invented the mercury thermometer and developed the Fahrenheit scale in 1724 | Temperature |

| | | |
|---|---|---|
|  <br>**Enrico Fermi** | **fermi (fm)**<br><br>Named after **Enrico Fermi**, the Italian physicist who made important contributions to the development of the first nuclear reactor. | Distance |
|  <br>**Godfrey Newbold Hounsfield** | **Hounsfield scale**<br><br>Named after **Sir Godfrey Hounsfield**, the British electrical engineer who invented the first computed tomography scanner. | Radiodensity |

| | | |
|---|---|---|
| **Karl Jansky** | **jansky (Jy)**<br><br>Named after **Karl Jansky**, the American physicist who discovered cosmic radio waves. | Electromagnetic flux |
|  <br>**Samuel Pierpont Langley** | **langley (ly)**<br><br>Named after **Samuel Pierpont Langley**, an American astronomer and physicist who made important contributions to the study of solar radiation. | Solar radiation |

| | | |
|---|---|---|
|  <br>**Irving Langmuir** | **langmuir (L)**<br><br>Named after **Irving Langmuir**, an American chemist and physicist who made important contributions to the study of surface chemistry. | Gas exposure dose |
|  <br>**Wilhelm Röntgen** | **röntgen (R)**<br><br>Named after **Wilhelm Röntgen**, the German physicist who discovered X-rays. | X-rays or gamma radiation |

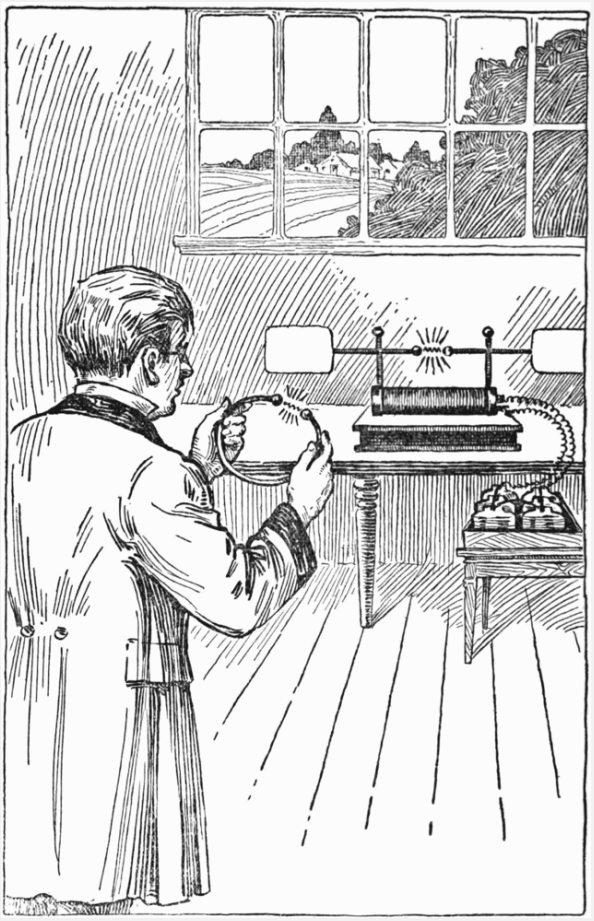
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|---|---|---|
|  <br>**Charles Francis Richter** | **Richter magnitude**<br><br>Named after **Charles Richter**, an American seismologist who developed the scale in 1935. | Earthquake |
|  <br>**Theodor Svedberg** | **svedberg (S or Sv)**<br><br>Named after **Theodor Svedberg**, a Swedish chemist and Nobel laureate who developed the ultracentrifuge, a device used to measure the sedimentation rate of particles in a solution. | Sedimentation rate |

| | | |
|---|---|---|
|  <br>**Evangelista Torricelli** | **torr (Torr)**<br><br>Named after **Evangelista Torricelli**, an Italian physicist who invented the mercury barometer in the 17th century. | Pressure |



It is often stated that of all the theories proposed in this century, the silliest is quantum theory. In fact, some say that the only thing that quantum theory has going for it is that it is unquestionably correct.

**— Michio Kaku**





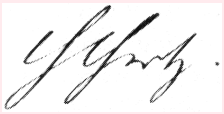


Image depicting the historical radio wave discovery made in 1886 by German scientist **Heinrich Hertz**

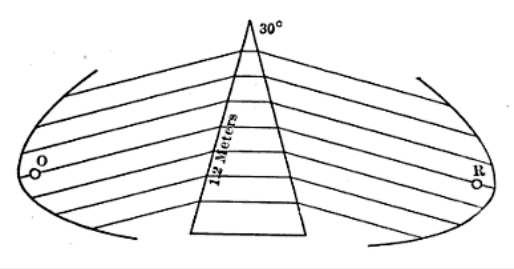
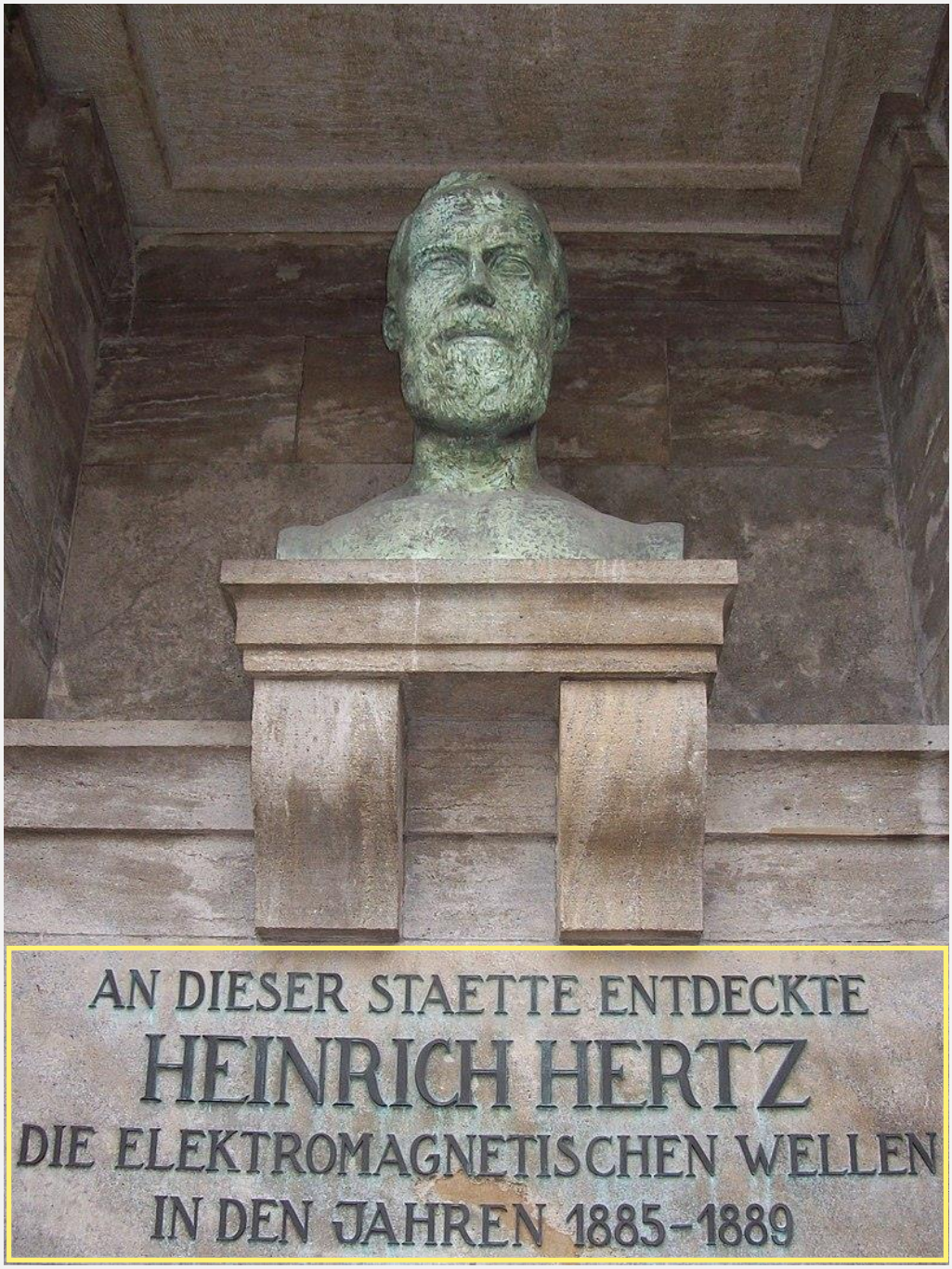



Illustration of Heinrich Hertz's 1888 experiment demonstrating the refraction of radio waves.

Similar to how light waves bend when passing through a prism formed of glass, radio waves also bend when they pass through a prism made of pitch.

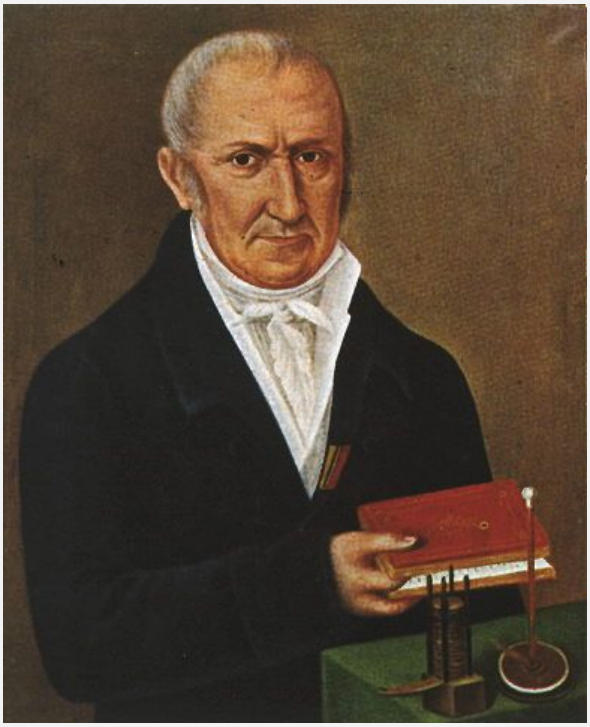



At this location, Heinrich Hertz discovered electromagnetic waves in the years 1885–1889.

**Memorial of Heinrich Hertz on the campus of the Karlsruhe Institute of Technology**



**Hans Christian Ørsted** (1777−1851) was a Danish physicist and chemist who is best known for his discovery of **electromagnetism**. In 1820, he observed that a compass needle was deflected when placed near a wire carrying an electric current, thus demonstrating a fundamental relationship between **electricity and magnetism**. This discovery paved the way for the development of electric generators, motors, and other technologies that rely on the **principles of electromagnetism**. **Ørsted** was also a professor of physics at the **University of Copenhagen** and made significant contributions to the study of acoustics, optics, and chemistry. He was a **prolific writer and lecturer**, and his popular science books helped to disseminate scientific knowledge to a broader audience. In recognition of his contributions to science, the **unit of magnetic field** strength, the **oersted**, is named after him.



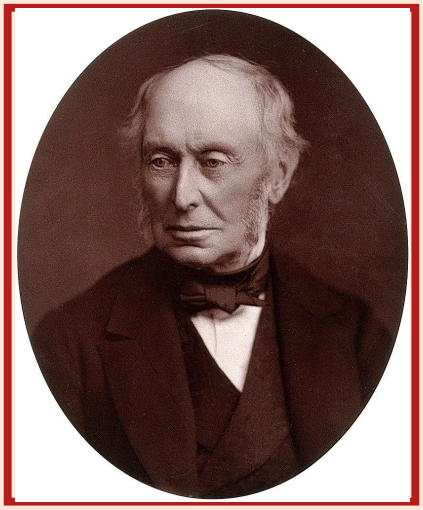
**Alessandro Volta** (1745−1827) was an Italian physicist who is best known for inventing the electric battery. He was born in Como, Italy, and received his education at the University of Pavia, where he later became a professor of physics. In 1800, Volta invented the first **electric battery**, which he called the **"voltaic pile."** The voltaic pile consisted of alternating layers of **zinc and copper discs**, separated by cardboard soaked in brine. When the top and bottom discs were connected with a wire, an electric current passed through the wire. This was the first time anyone had created a continuous flow of electricity, and it was a major breakthrough in the field of electricity. **Volta's invention of the electric battery** paved the way for many other important discoveries and inventions in the field of electricity. He was also the first person to isolate methane gas, and he made significant contributions to the study of **electrostatics and electrochemistry**. **Volta** was widely recognized for his contributions to science during his lifetime. He was awarded numerous honors and awards, including the Copley Medal from the Royal Society of London and the Order of the Iron Crown from the Austrian Empire. The **unit of electric potential**, the **volt**, is named after him in recognition of his contributions to the **study of electricity**.



**An image of a painting by Giuseppe Bertini of Alessandro Volta demonstrating his battery to Napoleone Buonaparte in 1801**

## Armstrong's hydroelectric effect

The Armstrong's hydroelectric effect is the physical process by which static electricity is produced by the friction of a fluid, such as steam or water droplets, against a solid surface. This phenomenon was first observed by **William George Armstrong** in 1840, when he noticed an electrical spark produced by the movement of water droplets in a steam boiler. The Armstrong's hydroelectric effect has practical applications in the generation of **static electricity** for industrial processes, such as electrostatic precipitation, where it is used to remove particles from industrial exhaust gases. It is also a subject of scientific research in the field of fluid dynamics and electrostatics.





| | |
|---|---|
| **Absolute zero** | 0 K |
| **Freezing point of water** | 273 K |
| **Boiling point of water** | 373 K |

1 Angstrom (Å) = $10^{-10}$ m

1 astronomical unit (AU) = $1.50 \times 10^{11}$ m

1 light-year (ly) = $9.46 \times 10^{15}$ m

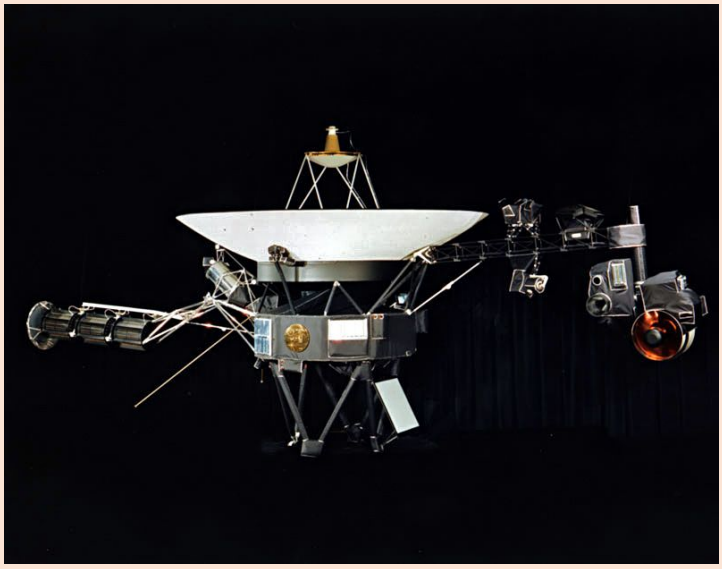
1 parsec (pc) = $3.09 \times 10^{16}$ m

1 kiloparsec (kpc) = 1000 pc

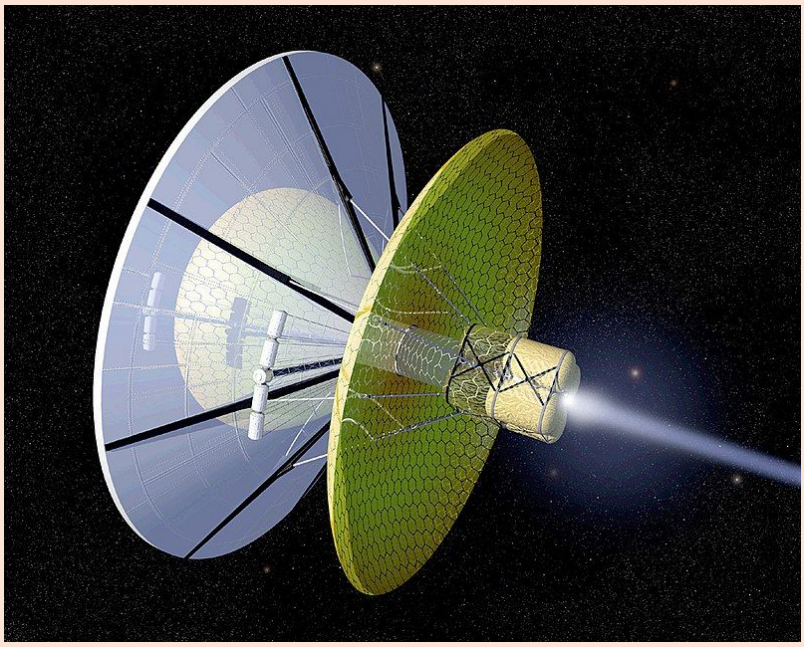
1 megaparsec (Mpc) = 1,000,000 pc

| | |
|---|---|
| **aphelion** | The orbital point of greatest distance from the sun |
| **perihelion** | The orbital point of closest approach to the sun |
| **apogee** | The orbital point of greatest distance from earth |
| **apparent visual magnitude** | The brightness of a star as seen by human eyes on earth |
| **aurora** | The glowing light display that results when the streams of electrified particles (**which are emitted by the sun**) trapped in the magnetic field of the earth |
| **black dwarf** | White dwarf that has cooled sufficiently that it no longer emits heat or light |
| **compact object** | A star that has collapsed to form a white dwarf, neutron star or a black hole |

**variation + natural selection → biological evolution**



**Voyager 1** was the first human-made spacecraft to reach the **interstellar space**. Entering the interstellar space was a significant milestone for **Voyager 1** and a momentous achievement for space exploration. It provided scientists with an opportunity to study the properties of the **interstellar space** beyond the influence of our Sun.



**Artist's conception of a Bussard ramjet**

The **Bussard Interstellar Ramjet engine**, also known as the **Bussard Ramjet**, is a theoretical concept for a spacecraft propulsion system that aims to utilize the interstellar medium as a source of propellant. It was originally proposed by physicist **Robert W. Bussard** in 1960. The basic idea is to collect interstellar hydrogen as the spacecraft moves through space and use it as fuel.

## Great Silence

The absence of any confirmed or conclusive evidence of extraterrestrial civilizations despite our efforts to detect them.

## Interstellar Communication

The transmission of information or signals between civilizations or entities located in different star systems or galaxies.

## Self-Destruction

**Advanced civilizations** tend to self-destruct before they can spread throughout the galaxy. The challenges and dangers associated with technological advancement, such as war, resource depletion, or environmental damage, may lead to the demise of civilizations.

## Technological transcendence

A **theoretical concept** in which human intelligence or consciousness surpasses its biological limitations through the use of **advanced technologies**. It envisions a future where humans integrate with machines, leading to enhanced cognitive abilities, expanded awareness, and potentially even immortality.

Because: $v = \sqrt{\frac{3k_B T}{m}}$

Lighter molecules or atoms tend to move faster than heavier molecules or atoms at the same temperature.

## Asteroid capture

The process of capturing an **asteroid** and altering its trajectory to bring it into a stable orbit around a celestial body such as the Earth, the Moon, or a space station.

## Panspermia

**Life** exists throughout the universe and can be distributed through **space** or transported between planets, moons, or even star systems, **carried by objects such as comets or asteroids**, leading to the possibility of life originating in one location and spreading to others.

## Technological singularity

A hypothetical future point in time at which artificial intelligence (AI) and other technological advancements reach a level where they surpass human intelligence and capabilities.

## Galactic Colonization

The expansion of human civilization beyond our solar system to other star systems and potentially throughout the Milky Way galaxy or even beyond.

## Astroecology

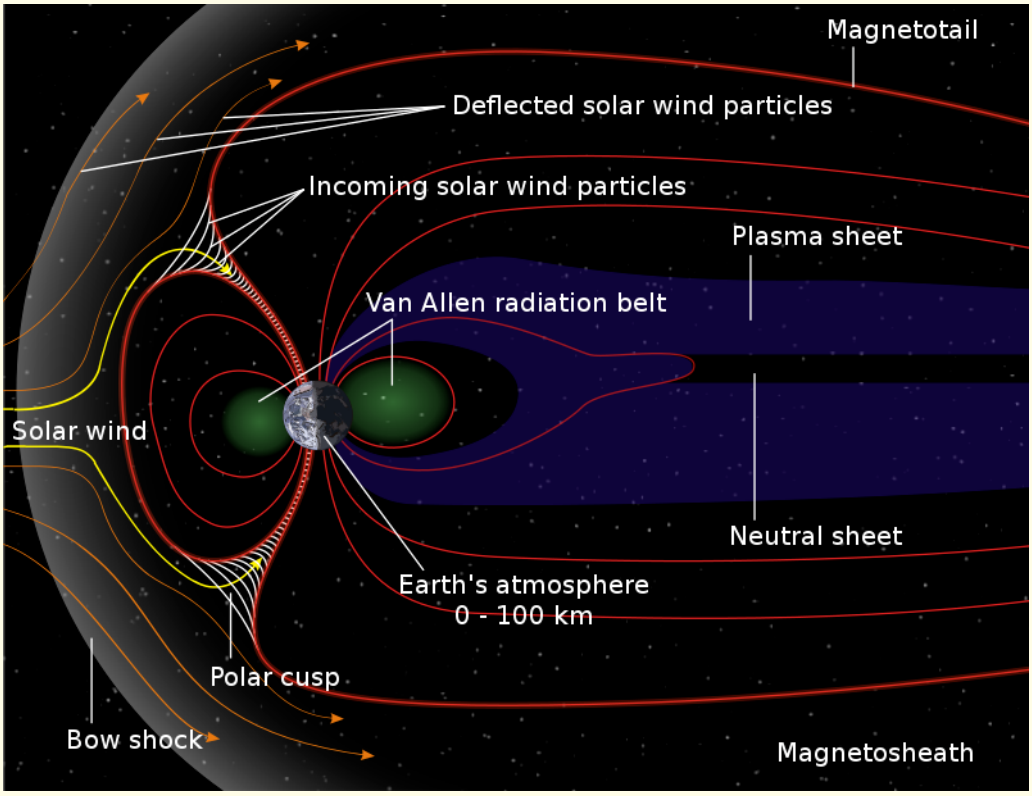
A field of study that explores the interactions between living organisms and their environment in space.

## Astrobiological Copernican Principle

Due to the vast number of planets in the universe, the emergence of life elsewhere is more likely to be a common occurrence rather than a rare phenomenon.

$$\text{Signal-to-Noise Ratio (SNR)} = \frac{\text{The power of the received signal}}{\text{The power of the background noise}}$$

The higher the Signal-to-Noise Ratio, the better the signal quality.




**Structure of the Earth's magnetosphere**

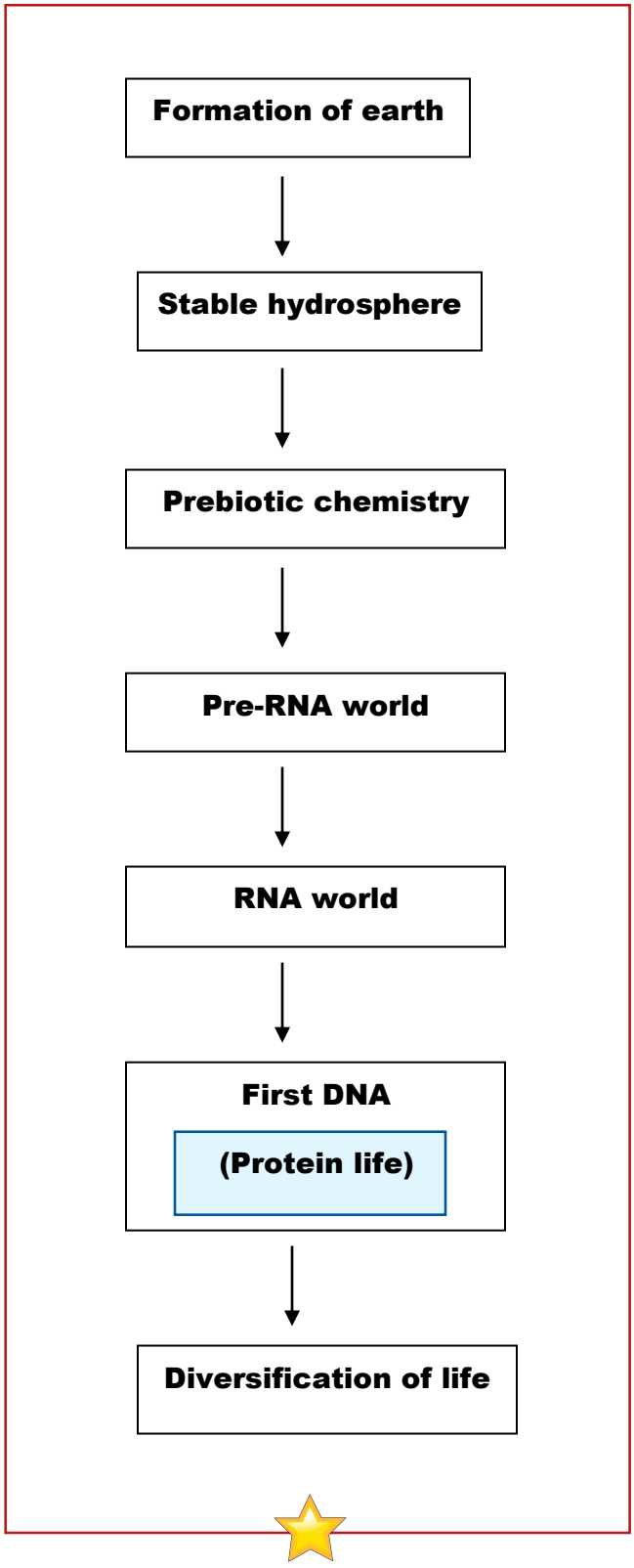
## Optical SETI

A branch of the broader field of **SETI** (Search for Extraterrestrial Intelligence) that focuses on the search for potential signals or messages from extraterrestrial civilizations using optical wavelengths of light.

## Astroarchaeology

The study of ancient extraterrestrial civilizations or their remnants.

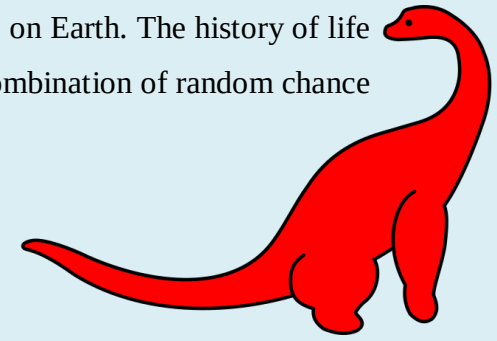
## ✓ Early history of life on Earth





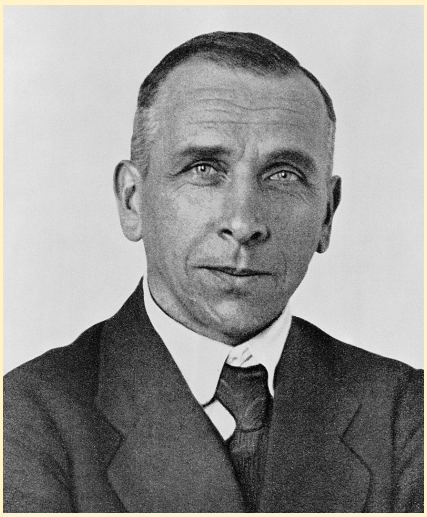
The **history of life on Earth** began around 3.8 billion years ago with the emergence of single-celled organisms. These simple life forms, known as prokaryotes, evolved over time to become more complex and diverse, eventually giving rise to all the different forms of life that we see today. The first major event in the history of life on Earth was the development of photosynthesis by certain prokaryotes around 3.5 billion years ago. This allowed these organisms to produce their own food using sunlight, rather than relying on organic matter in their environment. Photosynthesis also produced oxygen as a byproduct, which gradually built up in the atmosphere and paved the way for the development of more complex life forms. Around 2.4 billion years ago, the first eukaryotic cells evolved. These cells were larger and more complex than prokaryotes, and they had a nucleus and other membrane-bound organelles that allowed for more specialized functions. **Eukaryotic cells** eventually gave rise to all the different types of plants, animals, and fungi that we see today. Around 540 million years ago, a period known as the **Cambrian Explosion** occurred. This was a time of rapid diversification of life forms, and many of the major animal phyla that exist today first appeared during this period. This explosion of life was likely driven by a combination of factors, including rising oxygen levels, the evolution of new predatory strategies, and the development of new ecological niches. Throughout the rest of the **Paleozoic Era**, which lasted until around 250 million years ago, life on Earth continued to diversify and evolve. Plants and animals colonized land, and many new species of plants, insects, and vertebrates emerged. The **Mesozoic Era**, which began around 252 million years ago, was characterized by the dominance of the dinosaurs. These reptiles evolved into a wide variety of shapes and sizes, from the tiny **Compsognathus** to the enormous **Argentinosaurus**. Other notable groups that emerged during this era include the first birds and mammals. Around 65 million years ago, a mass extinction event wiped out the dinosaurs and many other species. This event was likely caused by a combination of factors, including a large asteroid impact and volcanic activity. The extinction paved the way for the rise of mammals, which had previously been restricted to small niches in the shadow of the dinosaurs. The **Cenozoic Era**, which began around 65 million years ago and continues to the present day, has been characterized by the further diversification of mammals and other groups of life. Humans first appeared around 2.5 million years ago, and have since evolved into the dominant species on Earth. The history of life on Earth is a story of constant change and adaptation, driven by a combination of random chance and the forces of natural selection.

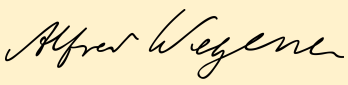






**George Ellery Hale** was an American astronomer who made significant contributions to the field of astrophysics and solar research. He is primarily known for inventing the **spectroheliograph**, an instrument used to capture detailed images of the Sun's surface and study its solar prominences.

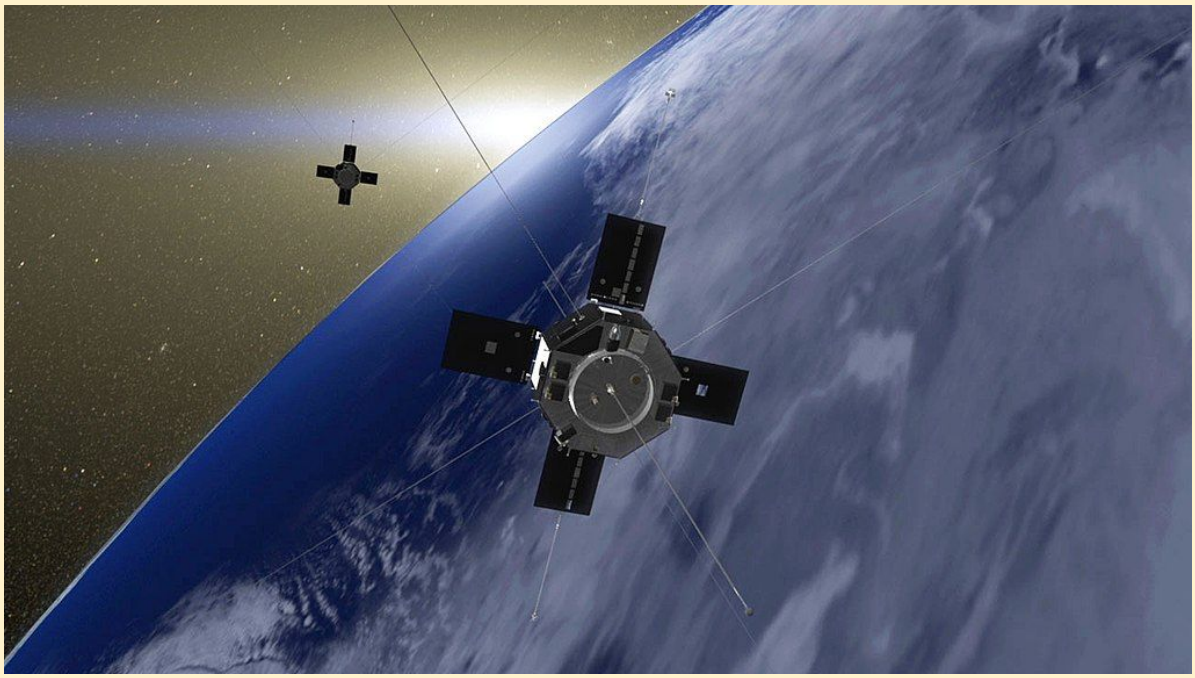




**Alfred Wegener**, a German geophysicist and meteorologist, proposed the theory of continental drift, which explains the slow shifting of continents over time. **Wegener** first presented this theory in 1912 in his book **"The Origin of Continents and Oceans."**



**James Alfred Van Allen** was an American space scientist who made significant contributions to the field of magnetospheric research and the study of Earth's radiation belts. His most notable achievement was the discovery of the radiation belts surrounding the Earth, which are now known as the **Van Allen radiation belts** in his honor.



**Artist's conception of Van Allen Probes in Earth orbit**



Are you aware that the speed at which our planet is orbiting the sun is 67,000 miles per hour?

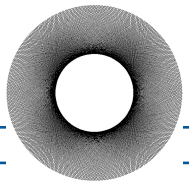
**The Apollo 17 crew captured a full disc Earth image on December 7, 1972, while travelling to the Moon at a distance of around 29,000 kilometers (18,000 miles). Africa, Antarctica, and the Arabian Peninsula are depicted.**

- **Cosmological Principle:** **The universe is the same everywhere.**
- **Homogeneous:** **The universe looks the same from every point.**
- **Isotropic:** **The universe looks the same in every direction.**

"We know that matter can be created out of energy, and energy can be created out of matter. This doesn't resolve the dilemma because we must also know where the original energy came from. – Why the Big Bang is a fizzle and stars cannot evolve out of gas... "

Thus the last and most successful creation of theoretical physics, namely quantum mechanics (QM), differs fundamentally from both Newton's mechanics, and Maxwell's e-m field. For the quantities which figure in QM's laws make no claim to describe physical reality itself, but only probabilities of the occurrence of a physical reality that we have in view.

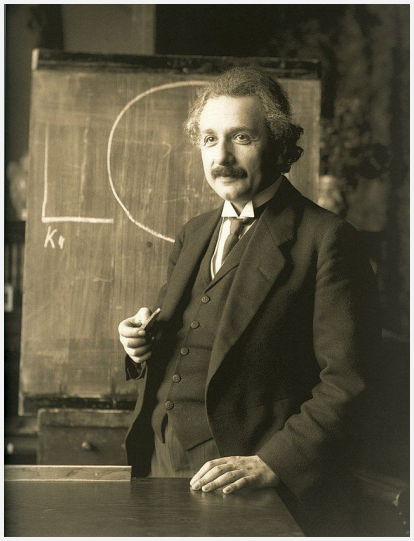
(Albert Einstein, 1931)



I cannot but confess that I attach only a transitory importance to this interpretation. I still believe in the possibility of a model of reality - that is to say, of a theory which represents things themselves and not merely the probability of their occurrence. On the other hand, it seems to me certain that we must give up the idea of complete localization of the particle in a theoretical model. This seems to me the permanent upshot of Heisenberg's principle of uncertainty.

(Albert Einstein, 1934)

Are there elementary particles that have not yet been observed, and, if so, which ones are they and what are their properties?

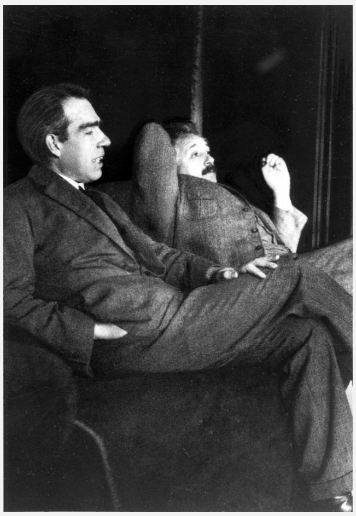


**Albert Einstein** during a lecture in Vienna in 1921

Although **Albert Einstein** is widely regarded as one of the greatest scientists of all time, he also faced a number of tragedies and setbacks throughout his scientific career. In the early part of his career, Einstein struggled to find academic employment. After graduating from the **Swiss Federal Institute of Technology** in 1900, he was unable to secure a university position and worked as a patent clerk in Bern, Switzerland. It was during this time, however, that he developed many of the ideas that would later lead to his groundbreaking discoveries in physics. **Einstein's** first major scientific contribution was his **theory of special relativity**, which he introduced in 1905. This theory challenged the fundamental assumptions of classical physics and showed that the laws of physics were the same for all observers in uniform motion. It also introduced the famous equation $\mathbf{E = mc^2}$, which showed the relationship between mass and energy.

Despite the significance of his work, **Einstein** initially struggled to gain acceptance from the scientific community. His theories were seen as **radical and unconventional**, and many physicists were skeptical of his ideas. It wasn't until the 1920s, when experiments confirmed many of his predictions that his work began to gain widespread recognition. Einstein's next major contribution to physics was his **theory of general relativity**, which he developed in the years following his work on **special relativity**. This theory showed that gravity was not a force, as had been assumed in classical physics, but was instead a curvature of spacetime caused by the presence of massive objects. **General relativity** was even more revolutionary than **special relativity**, and it fundamentally changed the way physicists understood the nature of the

universe. Despite the groundbreaking nature of his work, Einstein continued to face setbacks and controversies throughout his scientific career. In the 1920s, he became embroiled in a public debate with the physicist **Niels Bohr** over the interpretation of **quantum mechanics**, a branch of physics that deals with the behavior of subatomic particles. **Einstein** was deeply skeptical of quantum mechanics, which he saw as incomplete and inconsistent with the principles of classical physics.



**Niels Bohr and Albert Einstein.** The picture was taken at Ehrenfest's home in Leiden, the occasion was most likely the 50th anniversary of Hendrik Lorentz' doctorate (December 11, 1925).

Einstein's opposition to **quantum mechanics** put him at odds with many of his colleagues in the physics community, and his views were often seen as old-fashioned and out of touch. However, in the years following his death, many physicists began to reexamine **Einstein's criticisms of quantum mechanics** and to consider the possibility that he may have been onto something. Another tragedy that Einstein faced in science was his failure to develop a **unified field theory**, which would have reconciled his **theories of special and general relativity** with the **principles of electromagnetism**. Einstein spent much of his later career trying to develop a **unified theory**, but was ultimately unable to find a solution. This failure was a source of frustration for Einstein, who believed that a **unified theory** was necessary to truly understand the nature of the universe. Despite the setbacks and tragedies that **Einstein** faced throughout his scientific career, his work continues to have a profound impact on the field of physics. His **theories of relativity** fundamentally changed the way physicists understand space, time, and gravity, and his work on **quantum mechanics** helped to lay the groundwork for many of the advances in modern physics. Einstein's legacy as a scientist is one of innovation, perseverance, and a deep commitment to understanding the mysteries of the universe.

## Thomson's model

Thermionic emission, photoelectric emission, and ionization were all satisfactorily described by J.J. Thomson's 1900 proposal of the plum pudding atomic model, the first theoretical description of the interior structure of atoms. The model was not able to account for the scattering of alpha particles, nor did it address the question of where the spectral lines that were seen in the spectrum of hydrogen and other atoms came from.

- **Aufbau principle:** Electrons first enter the lowest energy orbitals.

- With a mass of $1.6750 \times 10^{-27}$ kg and a spin angular momentum of $\frac{\hbar}{2}$, the neutron is a fundamental neutral particle that is a necessary component of every nucleus with the exception of hydrogen atoms. It was found by **James Chadwick**, and it can enter a nucleus and trigger artificial nuclear disintegration.

| | |
|---|---|
| **Isotopes** | The atoms of an element with varying mass numbers but the same atomic number and chemical characteristics<br>**$_1H^1$, $_1H^2$ and $_1H^3$** |
| **Isobars** | The nuclei with the same mass number but differing atomic number and chemical properties<br>**$_1H^3$ and $_2He^3$** |
| **Isotones** | The nuclei with an equal number of neutrons<br>**$_6C^{13}$ and $_7N^{14}$** |
| **Mirror nuclei** | The nuclei with the same mass number but with atomic number differ by one<br>**$_1H^3$ and $_2He^3$** |

**Electromagnetic repulsion keeps nuclei from colliding at slow speeds. When moving fast, nuclei become near enough to one another that a strong force can bring them together.**

**Packing fraction**

↓

**Mass defect per nucleon**

**The nucleus is more stable the lower the packing fraction value.**

Binding energy per nucleon ∝ Stability of nucleus

**1 Becquerel = 1 disintegration per second,**

**1 Rutherford = $10^6$ disintegrations per second**

**1 Curie = $3.7 \times 10^{11}$ disintegrations per second**

**Intensity of light → energy incident per unit area in unit time**

$$\textbf{Intensity} = \frac{\text{Energy}}{\text{Area} \times \text{time}} = \frac{\text{Power}}{\text{Area}}$$

| Hard X-rays | Soft X-rays |
|---|---|
| X-rays with a frequency of the order of $\approx 10^{19}$ Hz and greater penetrating power | X-rays with a frequency of the order of $\approx 10^{16}$ Hz and lesser penetrating power |

- **Inertia of rest:** It is a body's inability to alter its state of rest on its own. This means that a body at rest will stay at rest and won't be able to move on its own.
- **Inertia of motion:** It is a body's inability to alter its state of motion on its own. This means that a body in uniform motion cannot accelerate or decelerate on its own.
- **Inertia of direction:** It is a body's inability to alter its direction of motion on its own.

**One atomic mass unit** is defined as one twelfth of the mass of an atom of carbon-12, which is an approximately $1.66054 \times 10^{-27}$ kilogram.

$$1 \text{ amu} = 1.66054 \times 10^{-27} \text{ kg}$$

- ✓ Mass of proton = 1.007276 amu
- ✓ Mass of neutron = 1.008665 amu
- ✓ Mass of electron = 0.00055 amu

$$E = mc^2 = \mathbf{1.66054 \times 10^{-27} \text{ kg} \times (2.9979 \times 10^{8} \text{ m/s})^{2}} = 14.923944519 \times 10^{-11} \text{ J}$$

Since $1 \text{ MeV} = 1.602 \times 10^{-13}$ J:

$$E = \frac{14.923944519 \times 10^{-11}}{1.602 \times 10^{-13}} \text{ MeV}$$

$$E = 931.5 \text{ MeV}$$

1 amu of mass is equivalent to 931.5 MeV of energy.

**Mass defect** refers to the difference between the mass of an atomic nucleus and the sum of the masses of its constituent protons and neutrons. The **mass defect** ($\Delta m$) can be calculated using the formula:

$$\Delta m = Zm_p + (A - Z)\, m_n - M$$

where Z is the atomic number, A is the mass number, $m_p$ is the mass of a proton, $m_n$ is the mass of a neutron and M is the mass of the nucleus. **Binding energy** is the amount of energy required to break apart a nucleus into its constituent protons and neutrons. This energy is released when the protons and neutrons are brought together to form a nucleus. The **binding energy** is a measure of the strength of the nuclear force that holds the nucleus together. The **binding energy** (BE) can be calculated using the formula:

$$BE = \Delta m \times c^2$$

where c is the speed of light. For $_2He^4$ nucleus this gives:

$$\Delta m = Zm_p + (A - Z)\, m_n - M$$

$$\Delta m = 2 \times 1.007276 \text{ amu} + (4-2) \times 1.008665 \text{ amu} - 4.001506 \text{ amu} = 0.030376 \text{ amu}$$

$$BE = \Delta m \times c^2 = 0.030376 \text{ amu} \times 1.66054 \times 10^{-27} \text{ (kg / amu)} \times (2.9979 \times 10^8 \text{ m/s})^2$$

$$BE = 0.030376 \times \mathbf{(1.66054 \times 10^{-27} \text{ kg} \times (2.9979 \times 10^8 \text{ m/s})^2)}$$

$$BE = 0.030376 \times 931.5 \text{ MeV} = 28.29 \text{ MeV}$$

This means that the **$_2He^4$ nucleus** is bound together by a total energy of **28.29 MeV**. The greater the binding energy, the more tightly bound the protons and neutrons are, and the more stable the nucleus is.

## Odd-Even rule of nuclear stability

- **Nuclear species** with odd numbers of both protons and neutrons are the least stable and more radioactive.
- **Nuclear species** with even numbers of both protons and neutrons are the most stable and less radioactive.
- **Nuclear species** with odd numbers of protons and even numbers of neutrons are less stable than **Nuclear species** with even numbers of protons and odd numbers of neutrons.

**Yukawa's meson theory** was proposed by Japanese physicist **Hideki Yukawa** in 1935. The theory suggested that there must be a new type of particle, which **Yukawa** called a **"meson,"** that was responsible for the strong nuclear force that binds protons and neutrons together in the atomic nucleus. **Yukawa** realized that the electromagnetic force, which is responsible for the interactions between charged particles, could not account for the strong force that held the nucleus together. He proposed that the meson was a mediator particle that transmitted the strong force between **nucleons** **(protons and neutrons)** in the nucleus. **Yukawa's meson** was later identified as a particle called the pi meson, which was discovered in 1947. The **pi meson** is a type of boson, which means it has integer spin and obeys **Bose-Einstein statistics**. **Yukawa's meson theory** was a major breakthrough in the understanding of nuclear physics and paved the way for the development of the modern theory of the strong nuclear force, which is currently explained by the **theory of quantum chromodynamics** (QCD).

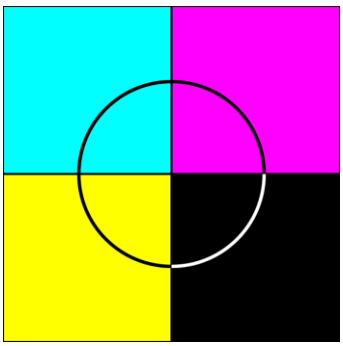


**The Earth's only natural satellite "Moon" most likely would have sailed away by now if gravitation didn't exist! Because of Earth's gravitational pull, it is held in its orbit around the Earth.**

**Are you aware that the tides in our oceans and seas are caused by gravity?**







**If you were in the Earth's center, you would feel weightless.**



**Black holes have the strongest gravitational pull in the entire universe.**

Weight = mass × acceleration due to gravity

$$W = m \times g$$

Let's assume the mass of the object remains constant at 100 kg on both Earth and Mercury.

$$W = 100\ kg \times g$$

**On Earth:**

$$W = 100\ kg \times 9.807\ m/s^2$$

$$W = 980.7\ N$$

**On Mercury:**

$$W = 100\ kg \times 3.7\ m/s^2$$

$$W = 370\ N$$

**Are you aware that you are taller in the morning than at night before you go to sleep?** This behavior may be brought on by gravitation squeezing cartilage in our knees and other body components, including our spine, when you stand and sit during the day.

An object with a mass of 100 kg would weigh 980.7 N on Earth and 370 N on Mercury.

The backwards-moving electron when viewed with time moving forwards appears the same as an ordinary electron, except that it is attracted to normal electrons - we say it has a positive charge. For this reason it's called a positron. The positron is a sister particle to the electron, and is an example of an anti-particle. ..This phenomena is general. Every particle in Nature has an amplitude to move backwards in time, and therefore has an anti-particle.

(Feynman, 1985)

For many years after Newton, partial reflection by two surfaces was happily explained by a theory of waves,* but when experiments were made with very weak light hitting photomultipliers, the wave theory collapsed: as the light got dimmer and dimmer, the photomultipliers kept making full sized clicks - there were just fewer of them. Light behaves as particles.

* This idea made use of the fact that waves can combine or cancel out, and the calculations based on this model matched the results of Newton's experiments, as well as those done for hundreds of years afterwards. But when experiments were developed that were sensitive enough to detect a single photon, the wave theory predicted that the clicks of a photomultiplier would get softer and softer, whereas they stayed at full strength - they just occurred less and less often. No reasonable model could explain this fact. This state of confusion was called the wave - particle duality of light.

**Fermi's Paradox:** If there are so many aliens where are they?

**(Feynman, 1985)**

The Coulombic repulsive force between two protons inside the nucleus is $10^{36}$ times the gravitational force between them. The nuclear attractive force between two neutrons is $10^{38}$ times the gravitational force between them.

- Very likely, we are missing something important. Why is gravity so weak?
- May because of hidden extra dimensions?

**The faster you move, the shorter and the heavier you are.**

**And that is the Theory of Relativity.**



| | |
|---|---|
| **Thermionic emission** | The process by which electrons are emitted from the surface of a heated metal |
| **Field emission** | The process by which electrons are emitted from the surface of a material in the presence of a strong electric field. |
| **Photoemission** | The phenomenon of electrons being emitted from a material when it is exposed to light of a certain frequency or energy |

When an electron with mass **m** and charge **e** is accelerated from rest through a potential difference **V**, it gains potential energy equal to **eV**. This potential energy is then converted into kinetic energy **KE** as the electron moves through the electric field.

$$\mathbf{KE = eV}$$

$$\frac{p^2}{2m_e} = \mathbf{eV}$$

$$\mathbf{p} = \sqrt{2m_e eV}$$

The d**e Broglie wavelength** $\lambda$ of an electron is given by the equation $\lambda = \frac{h}{p}$, where h is the Planck constant and p is the momentum of the electron.

$$\lambda = \frac{h}{\sqrt{2m_e eV}}$$

Substituting the numerical values of **h**, $\mathbf{m_e}$, **e**, we get:

$$\lambda = \frac{1.227}{\sqrt{V}} \text{ nm}$$

This equation shows that the **de Broglie wavelength** of an electron is inversely proportional to the square root of the potential V applied to it. This means that the shorter the **wavelength**, the higher the **potential** applied to the electron needs to be.

For:

**V** = 120 volts

$$\lambda = \frac{1.227}{\sqrt{120 \text{ volts}}} \text{ nm} \approx 0.112 \text{ nm.}$$

This wavelength is of the same order as the distance between the atomic planes in crystals

The rate of transfer of energy through a surface area

**Power = Energy flux × Surface area**

The energy flowing through the surface area per unit time

$$\textbf{Photons flux} = \frac{\text{Energy flux}}{\text{Energy of a photon}}$$

The number of photons crossing a unit area in a unit time

The energy emitted by a laser of power **P** watts in time **t** seconds is:

$$\mathbf{E = P \times t}$$

$$\mathbf{N\ hu = P \times t}$$

where **N** is the Number of photons emitted and **hu** is the energy of a emitted photon.

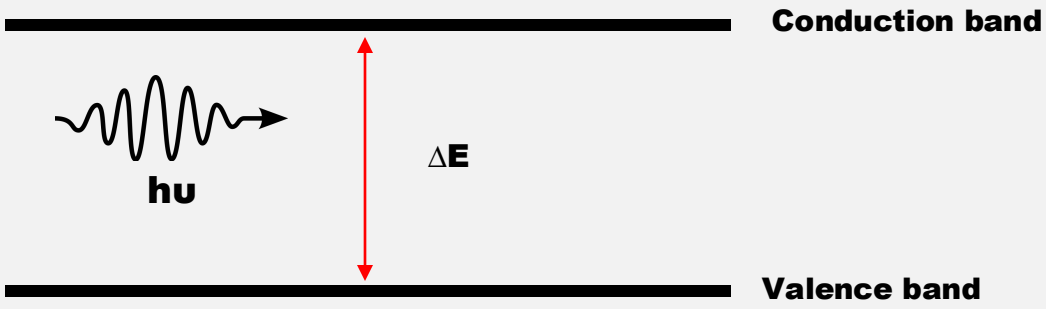
**For:**

$$\mathbf{P = 2\ mW = 2 \times 10^{-3}\ W}$$

$$\mathbf{t = 1\ s}$$

$$\mathbf{hu = 3.96 \times 10^{-19}\ J}$$

$$\mathbf{N} = \frac{2\text{mW} \times 1\text{s}}{3.96 \times 10^{-19}\text{J}} \approx 5.03 \times 10^{15} \text{ photons}$$




# $\Delta E \rightarrow$ band gap energy

The energy required to move an electron from the valence band to the conduction band. When an electron in the valence band absorbs energy from an incident photon, it can jump to the conduction band if the energy of the photon is equal to or greater than the **band gap energy**. The **band gap energy** can be calculated using the following formula:

$$\Delta E = h\nu = \frac{hc}{\lambda}$$

where **h** is the Planck's constant, **c** is the speed of light in vacuum, and $\nu = \frac{c}{\lambda}$ is the frequency and $\lambda$ is the wavelength of the incident photon.

**Momentum flux** = $\dfrac{\text{Energy flux}}{\text{Speed of light in vacuum}}$

→ The rate of transfer of momentum through a surface area

If $v_1$ and $v_2$ are the maximum velocities of the photoelectrons for the incident frequencies $\upsilon_1$ and $\upsilon_2$, then:

W is the work function of a given metal

$$\frac{m_e v_1^2}{2} = h\upsilon_1 + W$$

$$\frac{m_e v_2^2}{2} = h\upsilon_2 + W$$

$$\frac{m_e v_1^2}{2} - \frac{m_e v_2^2}{2} = h\upsilon_1 - h\upsilon_2$$

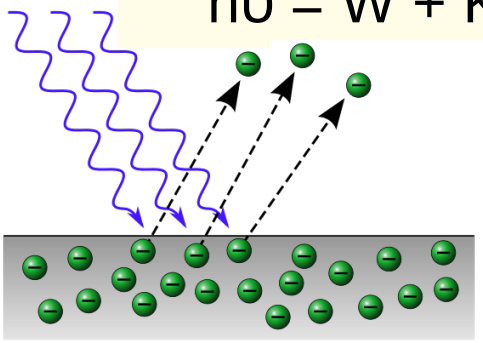
$$v_1^2 - v_2^2 = \frac{2h}{m_e}(\upsilon_1 - \upsilon_2)$$

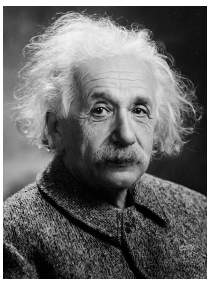
$$v_1^2 - v_2^2 = 4 \times \textbf{Quantum of circulation} \times (\upsilon_1 - \upsilon_2)$$

$$\approx 3.636\ 947\ 5520 \times 10^{-4}\ m^2/s$$

The smallest amount of circulation that can exist in a superfluid or a superconductor

$$h\upsilon = W + KE$$





**The quantum yield (Φ) of the photoelectric effect is:**

$$\Phi = \frac{\text{Number of electrons emitted}}{\text{Number of photons absorbed}}$$

This formula gives the ratio of the number of electrons emitted to the number of photons absorbed in a **photoelectric effect** process. **Here is an example to illustrate this formula:**

Suppose a photoelectric material is illuminated by 1000 photons of energy 3 eV each, and 800 electrons are emitted from the material. Then the **quantum yield of photoelectric effect** for this material can be calculated as:

$$\Phi = \frac{800}{1000} = 0.8$$

So the quantum yield of **photoelectric effect** for this material is 0.8 or 80%. This means that for every 100 photons absorbed by the material, 80 electrons are emitted from the material due to the **photoelectric effect**. It is important to note that the quantum yield can be less than 100% because not all absorbed photons result in **electron emission**, as some of the absorbed energy can be lost to other processes such as heat or recombination.

Black holes have no hair, says **No hair theorem**: Wait, What? Explaining the black hole



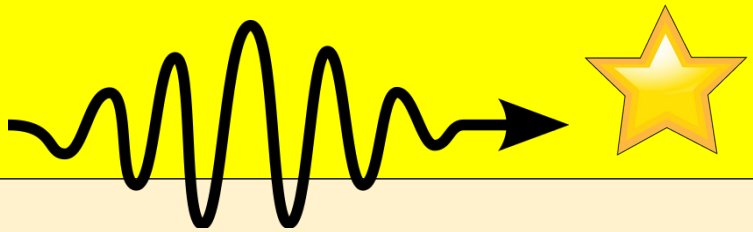
The answer is Simple:

**Mass, Charge and Angular Momentum**

The term "no hair" refers to the idea that black holes can be completely described by only a few parameters, such as their mass, electric charge, and angular momentum and they do not possess any additional distinguishing characteristics, such as the details of the matter that formed them or any other specific features.

Motion and gravity makes the clock tick slower.

**Did you know that the static on your television is caused by radiation left over from the Big Bang?**



## Grandfather paradox:

Let's say **John** is the one who discovers the time machine. He makes the decision to go back in time to a time before his father was born, when he meets his own grandfather, who is a young man at that time. In an unfortunate turn of events, **John** decides to kill his **grandfather**, thus preventing the birth of himself. Now, if **John** is successful in killing his **grandfather**, a contradiction would result. John could not have been born in the first place because John's grandfather died before he had any descendants. But **John** couldn't have gone back in time to murder his grandfather if he had never been born. Since the sequence of events cannot be consistently resolved, this creates a paradoxical loop.

## Bragg's law of diffraction

When **X-rays** with a specific wavelength "λ" hit the surface of a crystal at an angle "θ", they will be diffracted and produce **constructive interference** if the path length difference, **denoted as 2d sinθ**, between the diffracted waves from adjacent crystal planes is equal to an integer multiple of the wavelength " λ ". Mathematically, it can be represented as:

$$2d \sin\theta = n\lambda$$

where:

- d is the spacing between the crystal planes
- n is an integer representing the order of diffraction (1st order, 2nd order, etc.)

For example, let's assume:

$$\lambda = 10^{-10}\ \text{m}$$

$$d = 2 \times 10^{-10}\ \text{m}$$

$$\theta = 30\ \text{degrees}$$

$$2 \times 2 \times 10^{-10}\,\text{m} \times \sin(30°) = n \times 10^{-10}\,\text{m}$$

$$n = 0.5 \times 4 = 2$$

This means that the X-rays with a wavelength of $\lambda = 1$ Å (angstrom) striking the crystal with a lattice spacing of $d = 2$ Å at an angle $\theta = 30$ degrees will produce a bright spot in the diffraction pattern corresponding to the second order of diffraction.



**Georg Wulff**

A renowned **Russian crystallographer** who carried out in-depth research in crystallography, examining different crystal structures and their properties and making important contributions to the understanding of crystal symmetry, crystal morphology, and crystal formation.

# Twin paradox

The **twin paradox** is a thought experiment in special relativity that explores the concept of time dilation. It involves a scenario where one twin travels away from Earth at high speed, close to the **speed of light**, and then returns to Earth, while the other twin remains on Earth. When they are reunited, it is observed that the traveling twin has aged less than the twin who stayed on Earth.

The **index of refraction** is a property of a medium that describes how light or other electromagnetic waves propagate through it. It is defined as the ratio of the speed of light in a vacuum to the speed of light in the medium. The **index of refraction** (n) can be calculated using the following formula:

$$n = \frac{c}{v}$$

where:

- n is the index of refraction,
- c is the speed of light in a vacuum (approximately $3 \times 10^8$ meters per second),
- v is the speed of light in the medium.

For example, let's calculate the **index of refraction** for glass. The speed of light in a vacuum is $3 \times 10^8$ m/s, and the speed of light in glass is approximately $2 \times 10^8$ m/s. Using the formula, we can calculate the **index of refraction**:

$$n = \frac{3 \times 10^8 \text{ m/s}}{2 \times 10^8 \text{ m/s}} = 1.5$$

Therefore, the **index of refraction** for glass is 1.5. This means that light travels 1.5 times slower in glass compared to its speed in a vacuum.

## Free Fall

A body falling freely as a result of the earth's gravitational pull.

The formula for **free fall**, assuming negligible air resistance, is:

$$d = \frac{1}{2} \times g \times t^2$$

where:

- d is the distance travelled during free fall
- g is the acceleration due to gravity (approximately 9.8 $m/s^2$ on Earth)
- t is the time in seconds

Let's say we want to calculate the distance an object falls during free fall after 3 seconds. We can substitute the values into the formula:

$$d = \frac{1}{2} \times 9.8\ m/s^2 \times (3s)^2$$

d = 44.1 meters

Therefore, after 3 seconds of free fall, the object would have fallen approximately 44.1 meters.

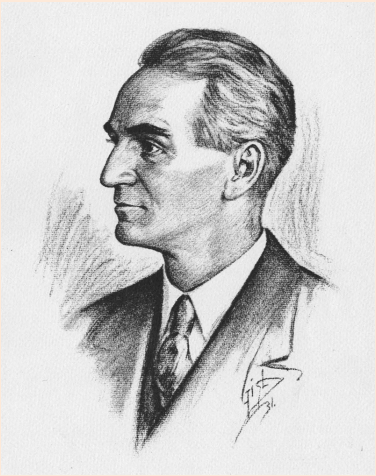


**Optical and X-ray Composite Image of Supernova SNR 0509-67.5**

**Long-duration gamma ray bursts** are associated with the deaths of massive stars in aspecific kind of explosion called a supernova.

**"Euclid taught me that without assumptions there is no proof.**

**Therefore, in any argument, examine the assumptions"**



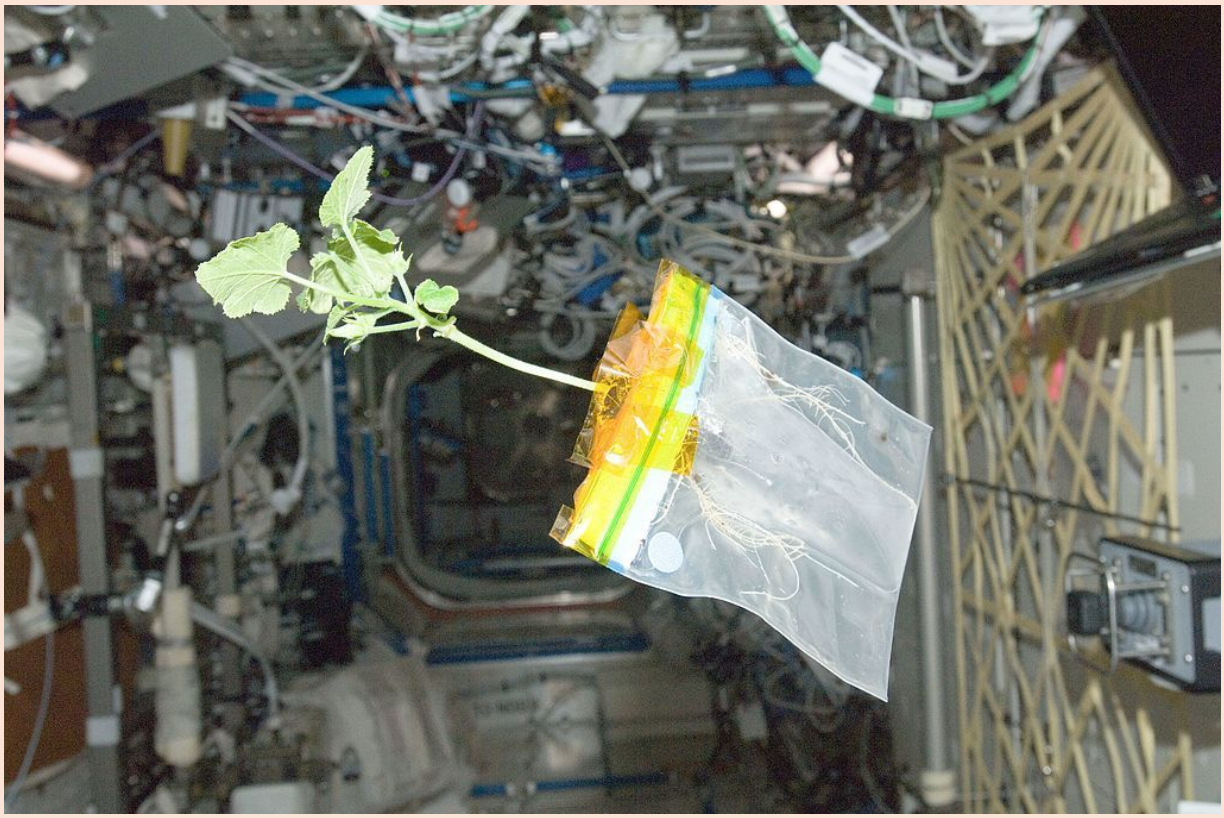
**–Eric Temple Bell**

## Carbon chauvinism

The assumption that life, particularly intelligent life, can only exist in environments similar to Earth and is dependent on carbon-based biochemistry.

## Astrobotany

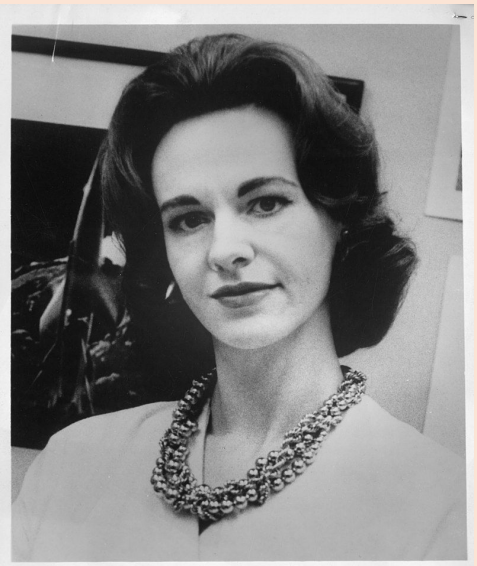
A field of study that focuses on the study of plants in space or in extraterrestrial environments.



**A zucchini being grown on the International Space Station (ISS)**

## Bioastronautics

A multidisciplinary field of **biological and astronautical research** that focuses on the study of the biological, physiological, and psychological effects of space travel on living organisms, particularly **humans**. It encompasses research and technologies aimed at understanding and mitigating the challenges of **human space exploration**.

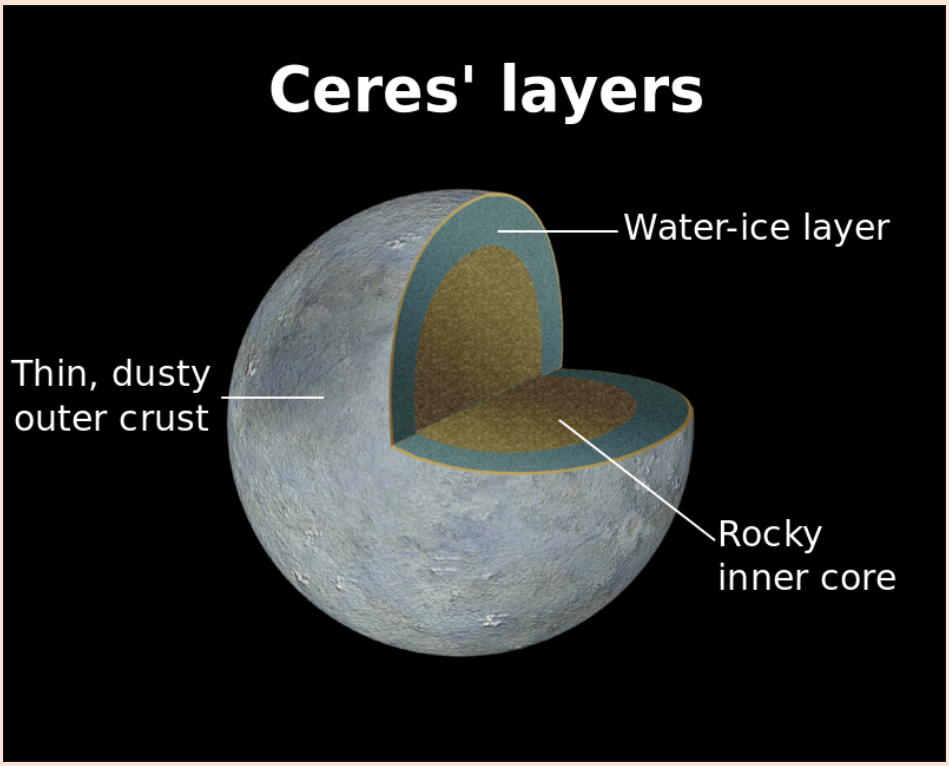


Miss Laurel van der Wal, Head of Bioastronautics
At Space Technology Laboratories, Receives 1961
Society of Women Engineers Achievement Award

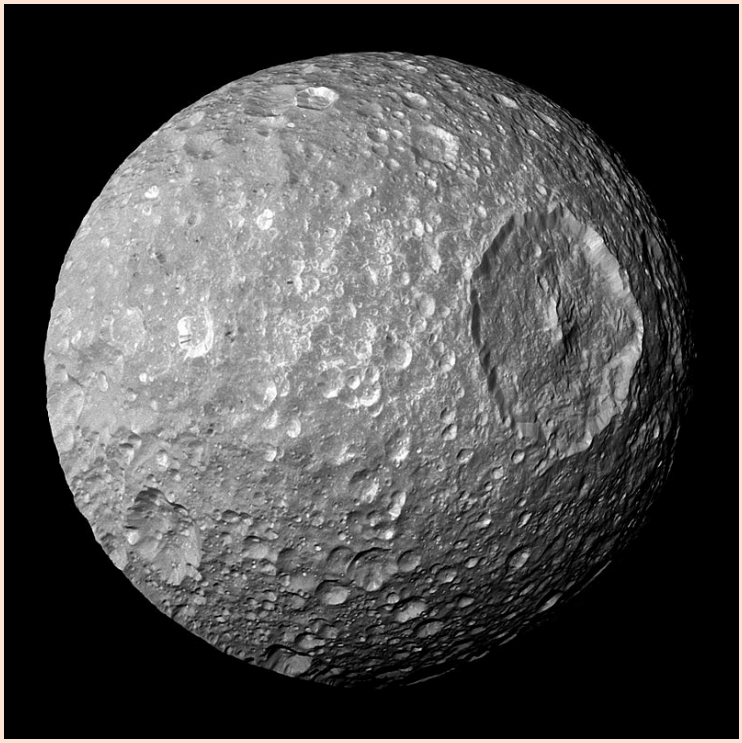
**Laurel van der Wal** who was the head of bioastronautics at Space Technology Laboratories, 1961

## Transient Technosignature

A temporary or short-lived signal or phenomenon that suggests the existence of advanced technological activity or artifacts in a particular location or region of space.




Internal structure of **Ceres**, a **dwarf planet** in the asteroid belt between the orbits of Mars and Jupiter.



**Mimas**, also known as **Saturn I**, is one of Saturn's natural satellites and is notable for possessing one of the largest impact craters on any moon in the Solar System. This crater is known as the **Herschel crater** and is a prominent feature on Mimas's surface.

$$T_{Planck} = \sqrt{\frac{\hbar c^5}{G k_B^2}}$$

The **Planck temperature** is the highest possible temperature that can exist in the universe, with a value of approximately $1.416 \times 10^{32}$ Kelvin. At temperatures above the **Planck temperature**, our current understanding of **physics breaks down**, and we require a theory that can describe these conditions. It is a fundamental constant in physics that has important implications for our understanding of the universe, particularly in the areas of **cosmology** and **quantum mechanics**. One of the most significant implications of the **Planck temperature** is that it represents the temperature at which the **four fundamental forces of nature** – gravity, electromagnetism, the strong nuclear force, and the weak nuclear force – are thought to be unified. This is known as the **Planck epoch**, which occurred within the first $10^{-43}$ seconds of the **Big Bang**. Understanding the behaviour of matter and energy during this epoch is crucial for developing a **unified theory of physics** that can describe all of the fundamental forces in a single framework. The **Planck temperature** also has important implications for black holes, which are objects with a **gravitational pull** so strong that not even light can escape from them. According to the formula: $T_{BH} = \frac{\hbar c^3}{8\pi G M k_B}$, as a black hole loses mass, its temperature increases, and it emits Hawking radiation at a faster rate. However, when a black hole temperature approaches the Planck temperature, a black hole would have a mass of $\frac{\text{Planck mass}}{8\pi}$. At this stage, the **classical description of black holes** based on **general relativity** is no longer sufficient, and a **theory of quantum gravity** is required to accurately describe the physics involved, as **quantum effects** play a crucial role in the dynamics of **spacetime** and the classical notions of space and time may break down. Investigating the behaviour of black holes at the **Planck scale** is crucial for understanding the interplay between gravity and quantum mechanics. The **Planck temperature** serves as the ultimate boundary for temperature in the realm of physics. According to current scientific understanding, speculating

about temperatures **hotter than** this limit is deemed **meaningless**, as it represents the highest possible temperature at which matter can exist. At temperatures exceeding the **Planck temperature**, the intense energy causes the disintegration of subatomic particles, resulting in a state where matter transitions entirely into energy.

**Black hole starship**

A theoretical concept that explores the possibility of using a black hole as a means of propulsion for interstellar travel.



**Marsha Ivins**, an American astronaut, demonstrates how the absence of gravity in the space environment alters the behaviour and appearance of hair, causing it to float and appear more voluminous compared to its behaviour on Earth.

The **kinetic energy** (KE) of a charged particle accelerated through a **potential difference** (V) can be calculated using the following equation:

$$KE = qV$$

This equation states that the **kinetic energy** of the charged particle of mass (m) is directly proportional to the product of its charge (q) and the potential difference it experiences.

$$\frac{mv^2}{2} = qV$$

$$v = \sqrt{\frac{2qV}{m}}$$

Electrons tend to move faster than protons under the influence of the same potential difference.

## Arecibo message

An **interstellar radio message**, transmitted in 1974, was designed as a representation of **human technological accomplishments** and contained fundamental details about Earth and humanity. Its purpose was to demonstrate of human achievements rather than to actively engage in a conversation with potential **extraterrestrial beings** in the **globular cluster Messier 13**.

## Superhabitable planet

A planet that could potentially support life forms in a more comfortable and sustainable manner compared to our own planet **Earth**.

- The discovery and confirmation of the cosmic microwave background radiation, or **CMBR**, in 1965 secured the **Big Bang** as the best theory of the origin and evolution of theuniverse…



**Nucleic acid was first isolated in 1869 by Johannes Friedrich Miescher.**

$$S_{BH} = \frac{k_B A}{4L^2_{Planck}}$$

"The **area formula** for the entropy — or number of internal states — of a black hole suggests that information about what falls into a black hole may be stored like that on a record, and played back as the black hole evaporates."



**– S.W. Hawking**

The objects of different masses are accelerated towards the earth at the same rate, but with different forces

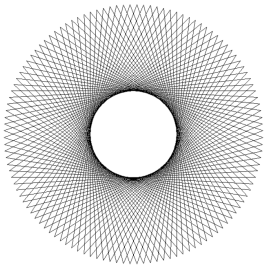
- $a = \frac{F}{m} = \frac{98\ N}{10kg} = 9.8\ m/s^2$
- $a = \frac{F}{m} = \frac{9.8\ N}{1kg} = 9.8\ m/s^2$

The physicist Leo Szilard once announced to his friend Hans Bethe that he was thinking of keeping a diary: "I don't intend to publish. I am merely going to record the facts for the information of God."

"Don't you think God knows the facts?" Bethe asked.

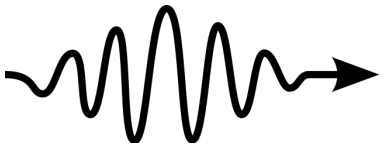
"Yes," said Szilard.

"He knows the facts, but He does not know this version of the facts."



**– Hans Christian von Baeyer, Taming the Atom**

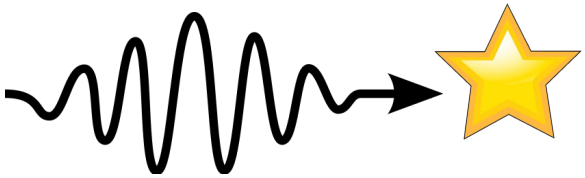
A virtual-particle pair has a wave function that predicts that both particles will have opposite spins. But if one particle falls into the black hole, it is impossible to predict with certainty the spin of the remaining particle.



**– S. W. Hawking**

- **Space:** the potential habitable worlds around ten thousand billion billion stars; ours is just one.
- **Time:** a cosmic history of nearly 14 billion years; life took less than ½ billion years to start here.

"If they not be inhabited, what a waste of space."

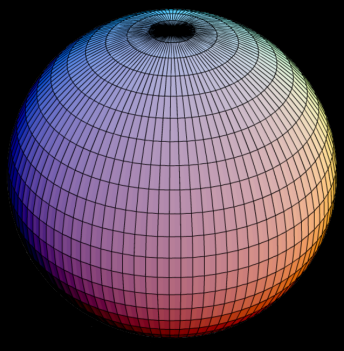


: Thomas Carlyle, Scottish Essayist (1795-1881)

**Gravitational lensing** is a phenomenon in which light from a distant object is bent and distorted by the gravitational field of a massive object, such as a galaxy or a cluster of galaxies, which lies between the distant object and the observer. The gravitational field acts as a lens, focusing or bending the path of light as it travels through space.

**Newton rings** is a phenomenon in which an interference pattern is created by the reflection of light between two surfaces — a spherical surface and an adjacent flat surface. It is named after Isaac Newton, who first studied them in 1717.

"Science is uncertain. Theories are subject to revision; observations are open to a variety of interpretations, and scientists quarrel amongst themselves. This is disillusioning for those untrained in the scientific method, who thus turn to the rigid certainty of the Bible instead. There is something comfortable about a view that allows for no deviation and that spares you the painful necessity of having to think."







**— Isaac Asimov**

- Strong force binds the nucleus
- Electromagnetic force binds the atoms
- Weak force induces radioactive decay
- Gravitational force binds the solar system

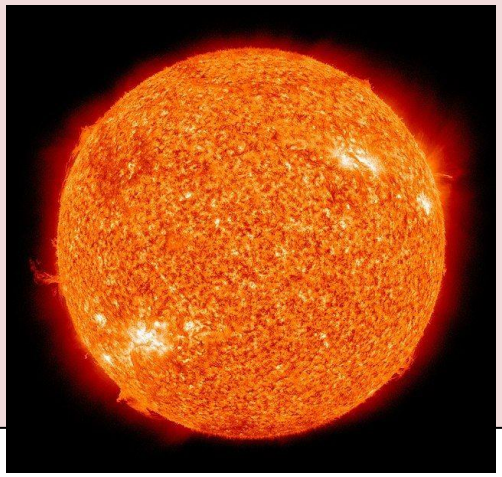
**Why the neutrinos only feel the weak force?**

**Atomic repulsion prevents matter from condensing into an extremely dense state while atomic attraction holds matter together.**

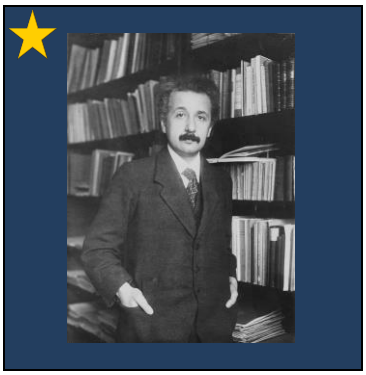
**Trojan asteroids** are asteroids that orbit larger planets in close proximity. A **meteoroid** is a term used to describe an asteroid or a portion of it that enters the Earth's atmosphere. There is a belief concerning **dinosaur extinction** which suggests that dinosaurs became extinct after a massive asteroid, roughly 10 km in diameter, impacted the Earth.

| | **Major constituent** |
|---|---|
| **Carbon Asteroids** | carbon |
| **Metallic Asteroids** | iron and nickel |
| **Stony Asteroids** | silica (silicon dioxide) |

The **Sun** is the largest and most massive object in our solar system. The Sun accounts for about 99.8% of the solar system's mass, which means that the remaining planets, moons, asteroids, comets, and other objects make up only about 0.2% of the total mass.

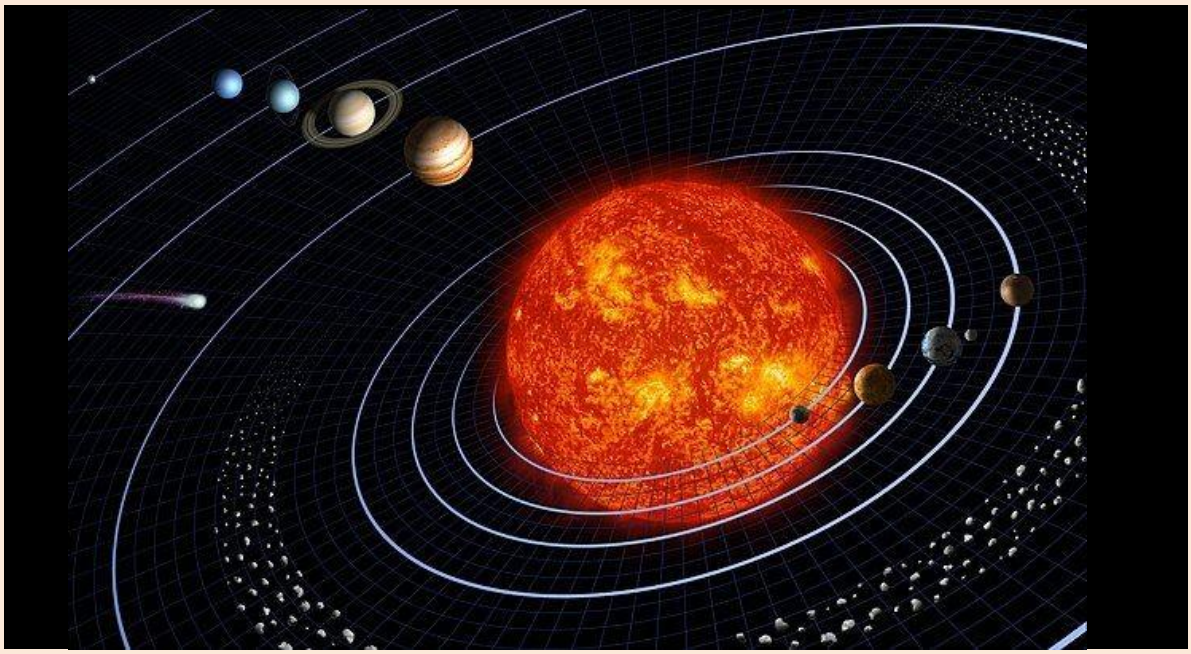


$E=mc^2$

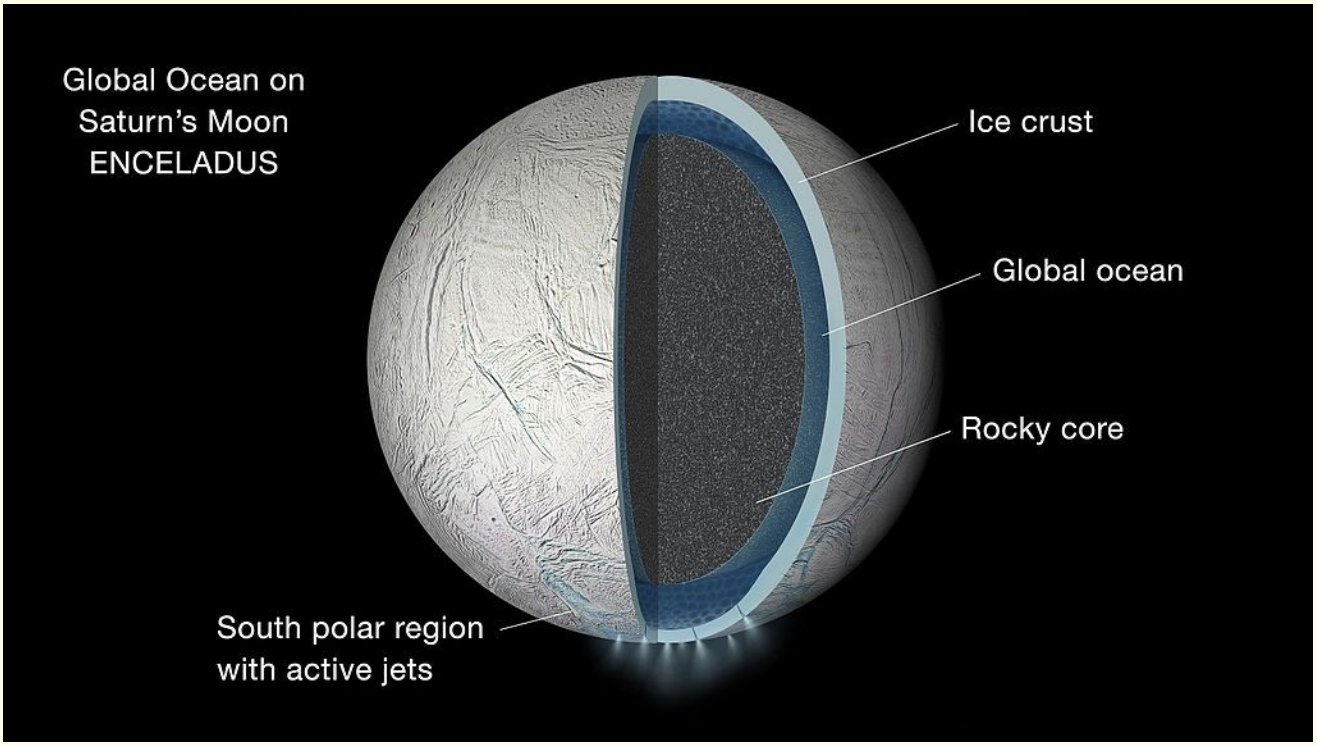


Einstein's equation that gave birth to the atom bomb and heralded a new world of atomic physics

**Due to the homogeneous distribution of galaxies throughout the visible universe, our universe has no center.**



The term **"galactic year"** or **"cosmic year"** refers to the duration of time it takes for the Sun to complete one orbit around the center of the **Milky Way** galaxy. This time period is estimated to be around 225 – 250 million years. The mass of our Milky Way galaxy is approximately 1.5 trillion times that of the Sun, and it spans a diameter of roughly 100,000 light-years.




**Artistic depiction of the interior of Saturn's moon "Enceladus" displaying a global liquid water ocean between its rocky core and icy crust.**

## Stoney mass:

$$m_S = \sqrt{\frac{e^2}{4\pi\varepsilon_0 G}} \approx 1.8592\times10^{-9}\ \text{kg}$$

$$m_S = \sqrt{\alpha} \times m_{Planck}$$

**Stoney mass = $\sqrt{\text{Fine structure constant}}$ × Planck mass**

## Stoney length:

$$L_S = \sqrt{\frac{Ge^2}{4\pi\varepsilon_0 c^4}} \approx 1.3807\times10^{-36}\ \text{m}$$

$$L_S = \sqrt{\alpha} \times L_{Planck}$$

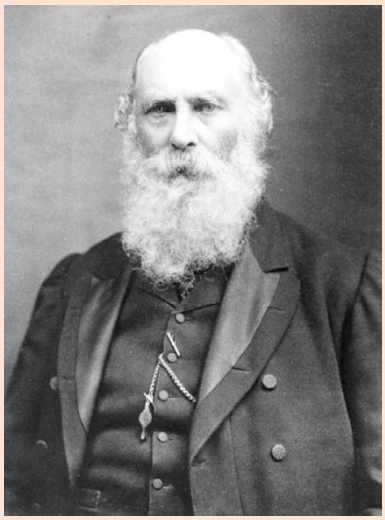
**Stoney length =** $\sqrt{\text{Fine structure constant}}$ **× Planck length**

## Stoney time:

$$t_S = \sqrt{\frac{Ge^2}{4\pi\varepsilon_0 c^6}} \approx 4.6054 \times 10^{-45}\ \text{s}$$

$$t_S = \sqrt{\alpha} \times t_{Planck}$$

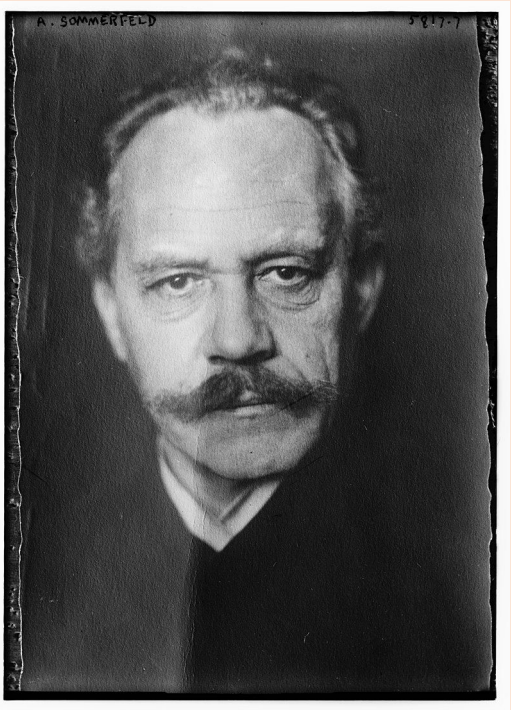
**Stoney time =** $\sqrt{\text{Fine structure constant}}$ **× Planck time**



**George Johnstone Stoney** (1826 – 1911) was an Irish physicist and mathematician who is best known for his pioneering work in the field of atomic and molecular physics. He was born in Dublin, Ireland and studied at Trinity College Dublin, where he later became a professor of natural philosophy. **George Stoney** is particularly known for his introduction of the concept of the electron in 1874. At the time, he referred to it as the **"elementary unit of electricity"**, but it was later renamed the electron by another scientist, **J.J. Thomson**. Stoney's work laid the groundwork for the development of modern atomic theory, and his contribution to the field of atomic and molecular physics was recognized by his election as a fellow of the Royal Society in 1892. In addition to his work on atomic theory, **George Stoney** also made important contributions to the study of optics and electromagnetism. He developed a new theory of light that emphasized the importance of the ether as a medium for the transmission of light waves, and he also made important contributions to the development of the theory of electrical conductivity. **George Stoney** was a prolific author who published numerous papers and articles on a wide range of topics in physics and mathematics throughout his career. He was widely respected by his colleagues and students for his intelligence, creativity, and dedication to the field of physics.

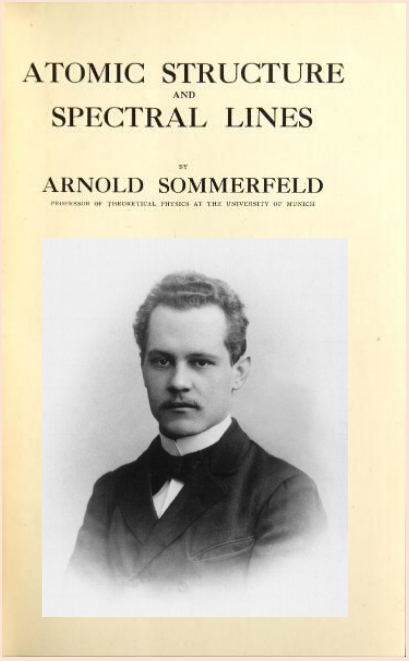



**Sommerfeld memorial at University of Munich**






**Arnold Johannes Wilhelm Sommerfeld**




The book **"Atomic Structure and Spectral Lines"** was written by **Arnold Sommerfeld** and published in 1923. **Sommerfeld** was a German physicist who made significant contributions to the development of quantum mechanics and atomic physics. In the book, **Sommerfeld** presents a detailed analysis of the atomic structure and spectral lines of various chemical elements. He begins by discussing the historical development of atomic theory and the work of key physicists such as **Bohr**, **Rutherford**, and **Einstein**. He then goes on to describe his own model of the atom, which extends the work of **Bohr** by taking into account the effects of relativistic motion and spin. **Sommerfeld** also discusses the experimental techniques used to study atomic spectra and the properties of atomic electrons, including the use of X-ray diffraction and spectroscopy. He explains how the analysis of spectral lines can provide information about the energy levels of atoms and their electronic configurations. The book is written in a highly technical and mathematical style, and is aimed primarily at advanced students and researchers in the field of atomic physics. However, it remains an important reference work for anyone interested in the history and development of atomic theory and quantum mechanics.

"Gravity is the force that rules the Universe. To understand its workings, to the finest degree, is to understand the very nature of our celestial home."

**— M. Bartusiak in Einstein's Unfinished Symphony**



The **circumference of the Earth** is approximately **40,075 kilometers (24,901 miles)** at the equator. If light were to travel around the Earth, it would have to cover this distance. The **speed of light** in a vacuum is approximately 299,792,458 meters per second. Therefore, the time it would take for light to travel around the Earth would be:

time = distance / speed

time = (40,075 km × 1000) / (299,792,458 m/s)

time ≈ 0.133 seconds

So, it would take about 0.133 seconds (or 133 milliseconds) for light to travel around the Earth at the equator.

"Science is a game — but a game with reality, a game with sharpened knives … If a man cuts a picture carefully into 1000 pieces, you solve the puzzle when you reassemble the pieces into a picture; in the success or failure, both your intelligences compete. In the presentation of a scientific problem, the other player is the good Lord. He has not only set the problem but also has devised the rules of the game — but they are not completely known, half of them are left for you to discover or to deduce. The experiment is the tempered blade which you wield with success against the spirits of darkness — or which defeats you shamefully. The uncertainty is how many of the rules God himself has permanently ordained, and how many apparently are caused by your own mental inertia, while the solution generally becomes possible only through freedom from its limitations."

**— Erwin Schrödinger**





## ✓ Did you know?

**Galileo Galilei was the first to use a telescope he built to observe celestial bodies.**

## ✓ Did you know?

**Hasan Ibn al-Haytham was the first person to create a visual picture of a solar eclipse. He created the picture with the aid of his own invention, a pinhole camera.**

"In a scientific sense, earthquakes are unpredictable. But that does not mean that you can't predict things about them."

**— PETER SAMMONDS**



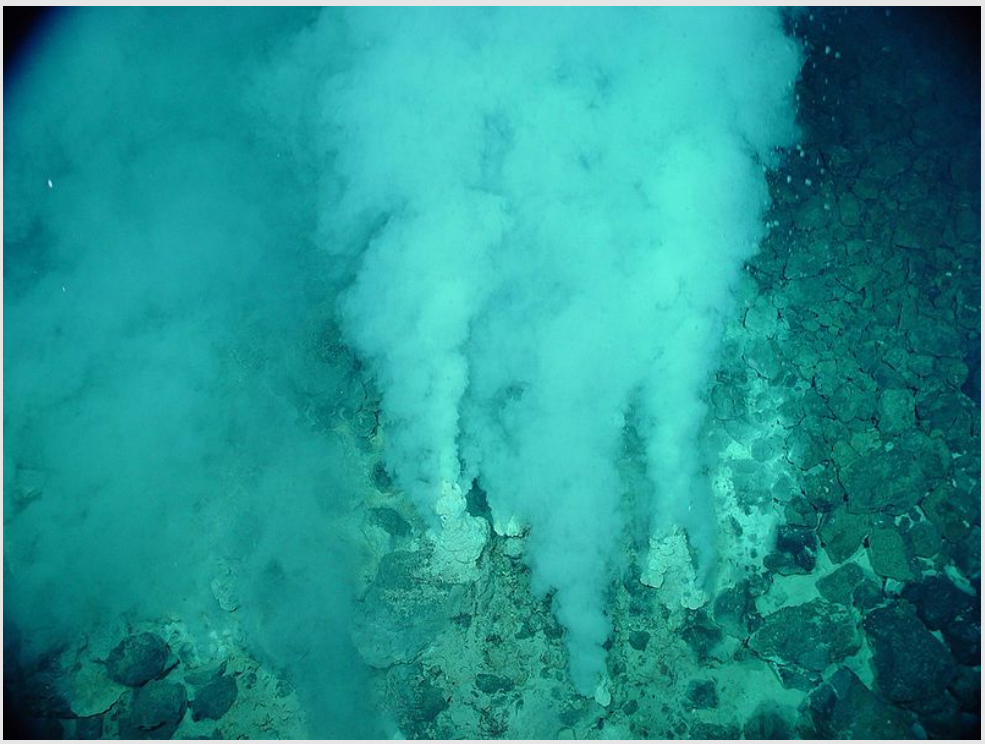


Neil Armstrong

**Only Apollo 11 has made a lasting impression on the majority of people in the globe. Since it was used to deliver Neil Armstrong and the other crew members to the Moon, where they first stepped foot in 1969.**

## Anthropocentrism

A **philosophical perspective** that places humans as the most significant and privileged beings, often regarding them as separate and superior to the rest of nature.



The earliest known life forms on Earth are **putative fossilized microorganisms** (microfossils) found in **white smoker hydrothermal vent precipitates**. These fossils are considered to be some of the oldest evidence of life on our planet. The age of these fossils has been estimated to be around **4.28 billion years old**.

## Quantum Astrobiology

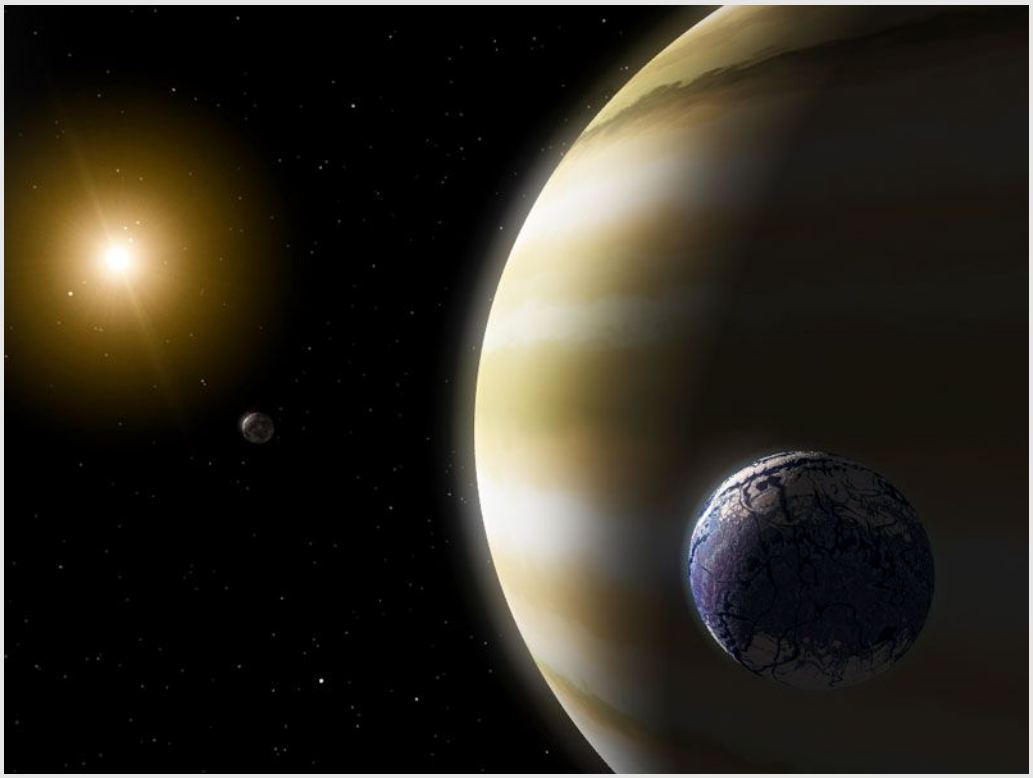
An interdisciplinary field that combines the principles of quantum physics and astrobiology to investigate the potential role of quantum phenomena in the origin, evolution, and nature of life in the universe.

## Iron–sulphur world hypothesis

Life may have originated in an environment rich in iron and sulphur minerals, rather than relying solely on organic molecules.

## Abiogenesis

The study of how life arises from non-living matter



An artistic depiction of an **Earthlike** satellite orbiting a large gas giant extrasolar planet.

## Non-Terran intelligence

The idea that **intelligent life** may exist beyond the confines of our planet and could possess diverse forms of consciousness, cognitive abilities, and technologies that are different from what we know on **Earth.**

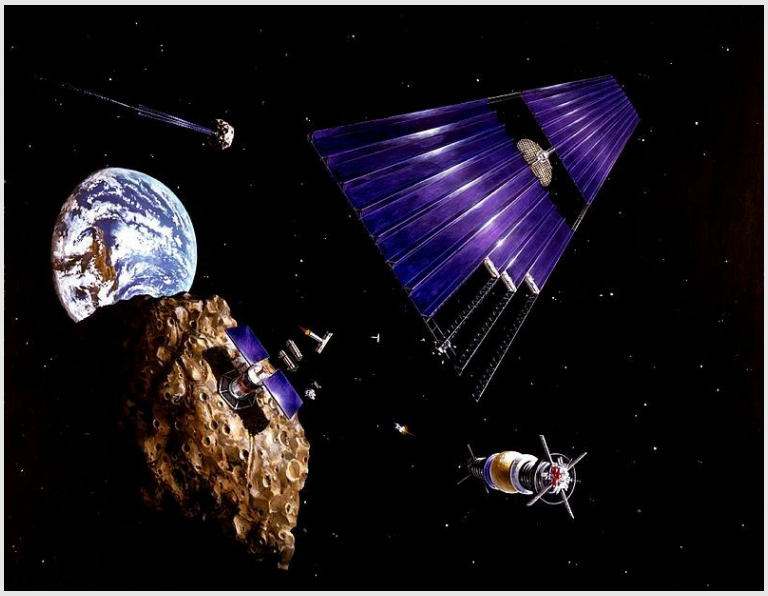
## Stellar engineering

The concept of manipulating or altering stars and their environments **through artificial means** to achieve certain desired outcomes or to harness their energy for advanced technological purposes



The **Keck Institute for Space Studies** created an illustration depicting a proposed approach for the **Asteroid Redirect Mission**, which involves the capture of an asteroid.

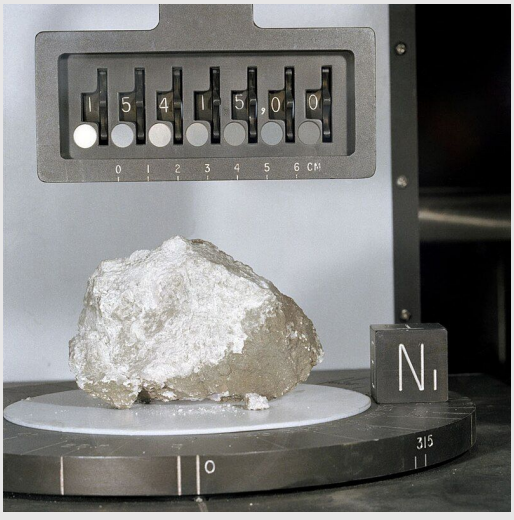
A proposed **space mission concept** by **NASA**, which aimed to demonstrate the ability to redirect an asteroid and bring it into a stable orbit around the Moon.



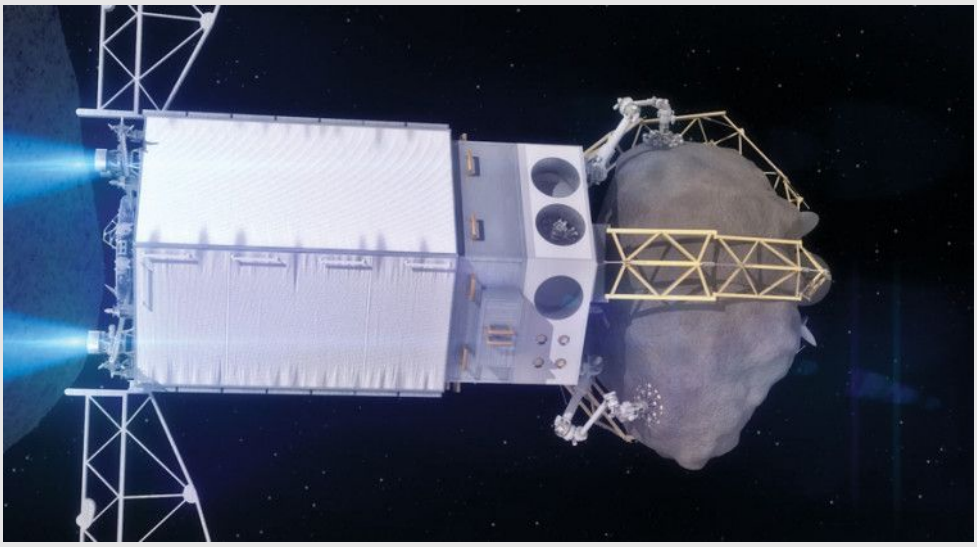
An Artistic conception of a mission to **mine an asteroid** that approaches Earth, showcasing the process of extracting valuable resources from the asteroid.

## Sample-return mission

A **space exploration mission** in which a spacecraft is sent to another **celestial body**, such as a planet, moon, or asteroid, with the **objective of collecting** samples from its surface or atmosphere and returning them to Earth for **scientific study** and analysis.




The **Genesis Rock**, which refers to a significant lunar sample collected during the **Apollo 15 mission**, which took place in 1971. It is officially known as **Sample 15415** and is considered one of the most important lunar samples brought back to Earth.



A depiction of the **Asteroid Redirect Vehicle** as it departs from the asteroid after successfully capturing a boulder from its surface.

## Asteroid impact avoidance

The collective **scientific and technological efforts and strategies** employed to divert or destroy potentially hazardous asteroids that pose a significant risk to our planet. The ultimate goal of **asteroid impact avoidance** is to safeguard human lives and mitigate the potential catastrophic consequences of a **large-scale impact of asteroids** or other celestial objects with Earth.

## Moving Earth

A speculative **astroengineering concept** that explores the idea of **physically relocating** the Earth to a different orbit, farther away from the Sun, in order to mitigate the potential consequences of **rising temperatures** on the **planet's biosphere**. This concept is often referred to as **"planetary relocation"** or **"orbital migration."**



"Who knows whether, when a comet shall approach this globe to destroy it ... men will not tear rocks from their foundations by means of steam, and hurl mountains, as the giants are said to have done, against the flaming mass?"

**— Lord Byron**

## Space architecture

The theory and practice of designing, planning, and implementation of living and working spaces, structures, and facilities that can support astronauts during their missions in outer space.



A 1990 artistic depiction of the **Space Station Freedom**, an ambitious project by **NASA** that later developed into what we now know as **the International Space Station** (ISS).

## Space tourism

The practice of traveling to space for recreational, leisure, or educational purposes.

## Simulated universes

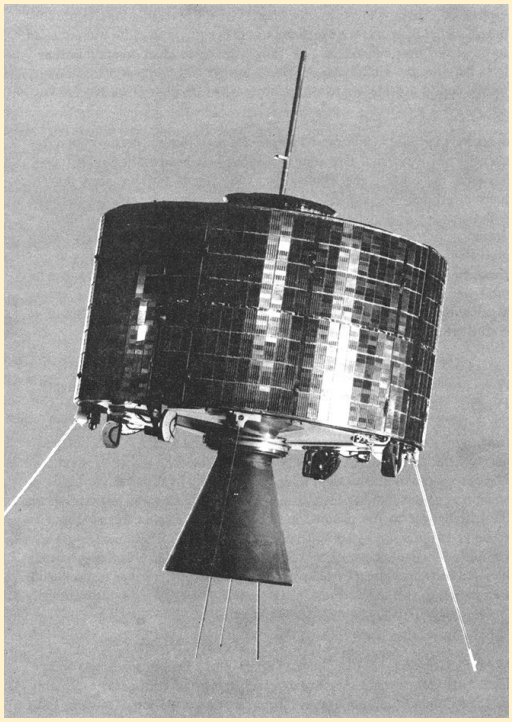
The hypothetical construct that propose the existence of computer-simulated or artificially created universes that mimic or simulate aspects of our own universe.




An artistic depiction of a **human mission** to Mars.

## Gravitational shielding

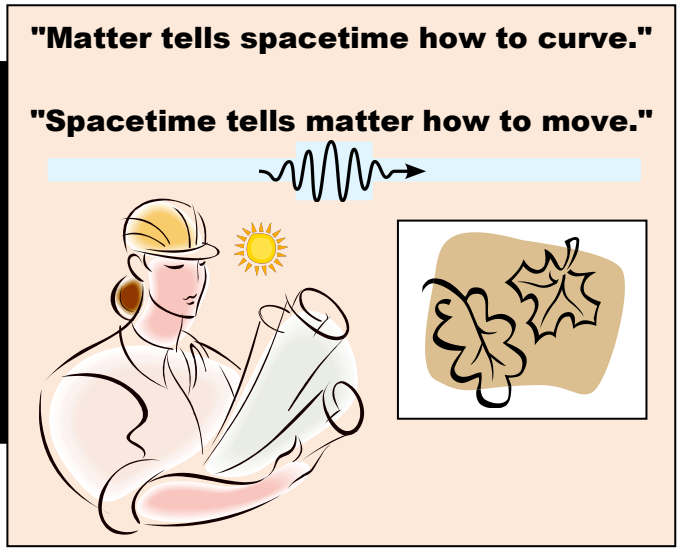
A hypothetical process of shielding an object from the influence of a gravitational field.



**Syncom 2**, launched on July 26, 1963, by NASA, was indeed the first satellite to be placed in **geosynchronous orbit** around the Earth.

$$G_{\alpha\beta} + g_{\alpha\beta}\,\Lambda = \frac{8\pi G}{c^4} T_{\alpha\beta}$$ (General Relativity with Λ)

$$G_{\alpha\beta} = \frac{8\pi G}{c^4} T_{\alpha\beta}$$ (General Relativity without Λ)




# Famous Scientists Who Changed the World



Isaac Newton in old age in 1712

**[1] Sir Isaac Newton**

Birth: Dec. 25, 1642 [Jan. 4, 1643, New Style], Woolsthorpe, Lincolnshire, England

Death: March 20 [March 31], 1727, London

Known for: the Newtonian Revolution

> *"Gravity explains the motions of the planets, but it cannot explain who sets the planets in motion."*
>
> *— Isaac Newton*

✓ William Stukely, who was a good friend of Newton's, wrote about Newton's Discovery in his ' **Memoirs of Sir Isaac Newton's life** ' in 1752.

He wrote:

' After dinner, the weather being warm, we went into the garden, and drank tea under the shade of some apple trees…he told me, he was just in the same situation as when formally, the notation of gravitation came to his mind.

"Why should that apple always descend perpendicularly to the ground," thought he to himself. '

✔ **Letter from Sir Isaac Newton to Richard Bentley (dated 17 January 1692/3)**



As to your first query, it seems to me that if the matter of our sun and planets and all the matter of the universe were evenly scattered throughout all the heavens, and every particle had an innate gravity toward all the rest, and the whole space throughout which this matter was scattered was but finite, the matter on the outside of this space would, by its gravity, tend toward all the matter on the inside and, by consequence, fall down into the middle of the whole space and there compose one great spherical mass. But if the matter was evenly disposed throughout an infinite space, it could never convene into one mass; but some of it would convene into one mass and some into another, so as to make an infinite number of great masses, scattered at great distances from one to another throughout all that infinite space. And thus might the sun and fixed stars be formed, supposing the matter were of a lucid nature.

But how the matter should divide itself into two sorts, and that part of it which is to compose a shining body should fall down into one mass and make a sun and the rest which is t to compose an opaque body should coalesce, not into one great body, like the shining matter, but into many little ones; or if the sun at first were an opaque body like the planets or the planets lucid bodies like the sun, how he alone should be changed into a shining body whilst all they continue opaque, or all they be changed into opaque ones whilst he remains unchanged, I do not think explicable by mere natural causes, but am forced to ascribe it to the counsel and contrivance of a voluntary Agent.

**– December 10, 1692**

But you argue, in the next paragraph of your letter, that every particle of matter in an infinite space has an infinite quantity of matter on all sides, and, by consequence, an infinite attraction every way, and therefore must rest in equili- brio, because all infinites are equal. Yet you suspect a paralogism in this argument; and I conceive the paralogism lies in the position, that all infinites are equal. The generality of mankind consider infinites no other ways than indefinitely; and in this sense they say all infinites are equal; though they would speak more truly if they should say, they are neither equal nor unequal, nor have any certain difference or proportion one to another. In this sense, therefore, no conclusions can be drawn from them about the equality, proportions, or differences of things; and they that attempt to do it usually fall into paralogisms.

So, when men argue against the infinite divisibility of magnitude, by saying, that if an inch may be divided into an infinite number of parts, the sum of those parts will be an inch; and if a foot may be divided into an infinite number of parts, the sum of those parts must be a foot; and therefore, since all infinites are equal, those sums must be equal, that is, an inch equal to a foot. The falseness of the conclusion shews an error in the premises; and the error lies in the position, that all infinites are equal.

**– January 17, 1693**



Albert Einstein in 1893 (age 14)

**[2] Albert Einstein**

Birth: March 14, 1879, Ulm, Wurttemberg, Germany

Death: April 18, 1955, Princeton, N.J., U.S.

Known for: **The 1905 Annus mirabilis papers**

- **On a Heuristic Point of View Concerning the Production and Transformation of Light** – which introduced the theory of the photon or light quantum.
- **On the movement of small particles suspended in stationary liquids required by the molecular-kinetic theory of heat**, related to Brownian movement, which provided sufficient arguments to leave the atomic theory of matter definitively settled.
- **On the electrodynamics of moving bodies** – where he established the basis for the special theory of relativity.
- **Does the inertia of a body depend on its energy content?** – In which he devised the formula which would later come to be written as $E = mc^2$.

*"The most beautiful experience we can have is the mysterious. It is the fundamental emotion that stands at the cradle of true art and true science."*

*— Albert Einstein*

✓ **Einstein letter to Professor G. Gamow (in August 4, 1946), with a comment handwritten by Gamow at the bottom**

**Dear Dr. Gamow**

After receiving your manuscript I read it immediately and then forwarded it to Dr. Spitzer. I am convinced that the abundance of elements as function of the atomic weight is a highly important starting point for cosmogonic speculations. The idea that the whole expansion process started with a neutron gas seems to be quite natural too. The explanation of the abundance curve by formation of the heavier elements in making use of the known facts of probability coefficients seems to me pretty convincing. Your remarks concerning the formation of the big units (nebulae) I am not able to judge for lack of special knowledge.

Thanking you for your kindness, I am

yours sincerely,

Albert Einstein

(*Of course, the old man agrees with almost anything nowadays*

– Comment handwritten by Gamow

## ✓ Einstein's Letter to Mathematician David Hilbert

When Marie Curie was denied a seat in the French Academy of Sciences and Einstein sent a letter of support, he also wrote a sensitive note to Hilbert seeking to put disagreements behind and to rekindle their friendship. It says:

There was a moment in which something like as irritation came between us, the origin of which I no longer want to analyze. I have fought against the bitterness which it provoked in me, and have succeeded completely in doing so. I again think of you with unclouded friendship, and I ask you to do the same for me. It is really a pity if companions such as we are, who have managed to forge a path aside from the pettiness of this world, could find anything other than joy in each other's company.

## Einstein Letter to Franklin D. Roosevelt, dated August 2, 1939.

Sir:



Einstein with his second wife, Elsa, in 1921

Some recent work by E. Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable — through the work of Joliot in France as well as Fermi and Szilard in America — that it may become possible to set up a nuclear chain reaction in a large mass of uranium by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This phenomenon would also lead to the construction of bombs, and it is conceivable—though much less certain — that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium is Belgian Congo.

In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an inofficial capacity. His task might comprise the following:

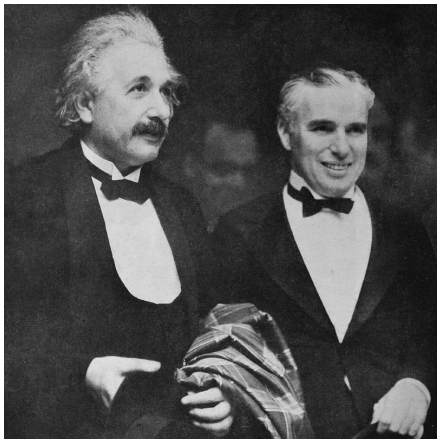
a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States.

b) to speed up the experimental work, which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of industrial laboratories which have the necessary equipment.



Einstein in 1904 (age 25)

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsäcker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated.



Albert Einstein (left) and Charlie Chaplin at the Hollywood premiere of City Lights, January 1931

Yours very truly,

Albert Einstein

## Letter from Albert Einstein to Chaim Weizmann

Dear Mr. Weizmann,

I have read with great satisfaction that the Palestinian Jewry has made you head of the new state. This is at least a partial reparation for the ungrateful attitude they have shown towards you and your great accomplishments. One still cannot say that the powerful men of this earth mean well with us. The game the English play with us is miserable, and the American attitude appears ambivalent.

However, I am confident that our people will overcome this last scare and that you will live to experience the satisfaction of having created a happy Jewish community.

With heartfelt greetings and best wishes,

Your A. Einstein



Einstein at the age of three in 1882

## A letter from Albert Einstein to his daughter: on The Universal Force of Love

"When I proposed the theory of relativity, very few understood me, and what I will reveal now to transmit to mankind will also collide with the misunderstanding and prejudice in the world.

I ask you to guard the letters as long as necessary, years, decades, until society is advanced enough to accept what I will explain below.

There is an extremely powerful force that, so far, science has not found a formal explanation to. It is a force that includes and governs all others, and is even behind any phenomenon operating in the universe and has not yet been identified by us. This universal force is LOVE.

When scientists looked for a unified theory of the universe they forgot the most powerful unseen force. Love is Light, that enlightens those who give and receive it. Love is gravity, because it makes some people feel attracted to others. Love is power, because it multiplies the best we have, and allows humanity not to be extinguished in their blind selfishness. Love unfolds and reveals. For love we live and die. Love is God and God is Love.

This force explains everything and gives meaning to life. This is the variable that we have ignored for too long, maybe because we are afraid of love because it is the only energy in the universe that man has not learned to drive at will.

To give visibility to love, I made a simple substitution in my most famous equation. If instead of $\mathbf{E = mc^2}$, we accept that the energy to heal the world can be obtained through love multiplied by the speed of light squared, we arrive at the conclusion that love is the most powerful force there is, because it has no limits.

After the failure of humanity in the use and control of the other forces of the universe that have turned against us, it is urgent that we nourish ourselves with another kind of energy…

If we want our species to survive, if we are to find meaning in life, if we want to save the world and every sentient being that inhabits it, love is the one and only answer.

Perhaps we are not yet ready to make a bomb of love, a device powerful enough to entirely destroy the hate, selfishness and greed that devastate the planet.

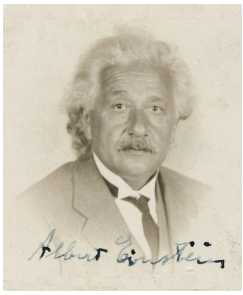
However, each individual carries within them a small but powerful generator of love whose energy is waiting to be released.

When we learn to give and receive this universal energy, dear Lieserl, we will have affirmed that love conquers all, is able to transcend everything and anything, because love is the quintessence of life.

I deeply regret not having been able to express what is in my heart, which has quietly beaten for you all my life. Maybe it's too late to apologize, but as time is relative, I need to tell you that I love you and thanks to you I have reached the ultimate answer! ".

Your father,

Albert Einstein



## ✓ Letter from Albert Einstein to the Jewish philosopher Eric B. Gutkind

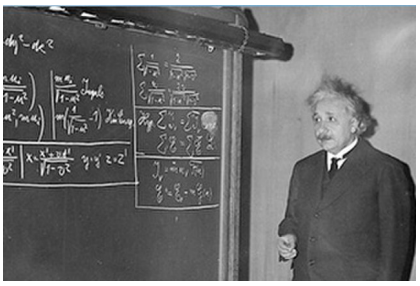
The word God is for me nothing more than the expression and product of human weaknesses, the Bible a collection of honorable, but still primitive legends which are nevertheless pretty childish. No interpretation no matter how subtle can (for me) change this. These subtilised interpretations are highly manifold according to their nature and have almost nothing to do with the original text. For me the Jewish religion like all other religions is an incarnation of the most childish superstitions. And the Jewish people to whom I gladly belong and with whose mentality I have a deep affinity have no different quality for me than all other people. As far as my experience goes, they are also no better than other human groups, although they are protected from the worst cancers by a lack of power. Otherwise I cannot see anything 'chosen' about them.

In general I find it painful that you claim a privileged position and try to defend it by two walls of pride, an external one as a man and an internal one as a Jew. As a man you claim, so to speak, a dispensation from causality otherwise accepted, as a Jew the privilege of monotheism. But a limited causality is no longer a causality at all, as our wonderful Spinoza recognized with all incision, probably as the first one. And the animistic interpretations of the religions of nature are in principle not annulled by monopolization. With such walls we can only attain a certain self-deception, but our moral efforts are not furthered by them. On the contrary.

Now that I have quite openly stated our differences in intellectual convictions it is still clear to me that we are quite close to each other in essential things, i.e; in our evaluations of human behavior. What separates us are only intellectual 'props' and 'rationalization' in Freud's language. Therefore I think that we would understand each other quite well if we talked about concrete things.

With friendly thanks and best wishes,

Yours, A. Einstein



Albert Einstein near a blackboard with special relativity formulae, before 1940.

**Imagination is more important than knowledge.**

**Knowledge is limited. Imagination encircles the world.**

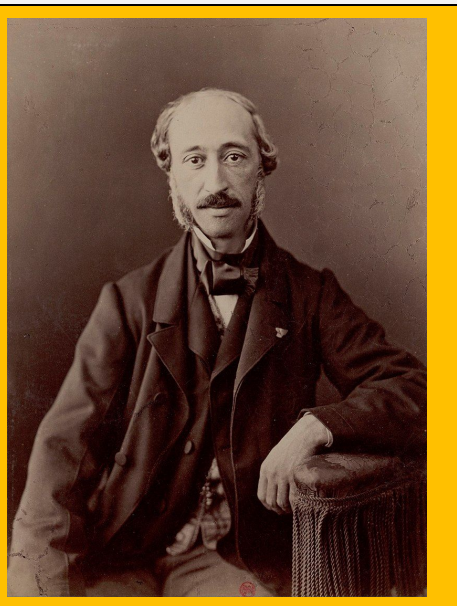
**— Albert Einstein**





**Published in the USA in 1920, this image shows Albert Einstein working in his office at the University of Berlin.**

The **photoelectric effect** is a phenomenon where electrons are emitted from a metal surface when it is exposed to electromagnetic radiation, such as light. The discovery of this effect was an important milestone in the development of **quantum mechanics**, and it was **Albert Einstein** who first proposed a theoretical explanation for it in 1905.



**Alexandre-Edmond Becquerel**



**Heinrich Hertz**

The **photoelectric effect** was first observed by the French physicist **Alexandre-Edmond Becquerel** in 1839, when he discovered that certain materials, such as potassium and uranium, emitted electrons when exposed to light. However, it was not until the late 19th and early 20th centuries that the phenomenon was more fully understood. In 1887, the German physicist **Heinrich Hertz** discovered that when ultraviolet light was shone on a metal plate, it produced sparks between two electrodes. This discovery was an early demonstration of the **photoelectric effect**, although **Hertz** did not fully understand the underlying mechanism. In 1900, the German physicist **Max Planck** proposed his **theory of blackbody radiation**, which described how the energy of electromagnetic radiation was quantized into discrete packets or **"quanta".** This idea was a precursor to the concept of photons, which would later be used to explain the photoelectric effect. In 1902, the American physicist **Arthur Compton** observed that the energy of scattered X-rays was related to the frequency of the incident X-rays, providing further evidence for the quantization of electromagnetic radiation. In 1905, **Albert Einstein** published his paper on the

**photoelectric effect**, which proposed that light was made up of particles, or photons, and that these photons transferred their energy to electrons in a metal when they struck its surface, causing the electrons to be ejected from the surface. This is because the energy of the photon is absorbed by the electron, giving it enough energy to overcome the **binding forces** that hold it in the metal. The energy of a photon is directly proportional to its frequency, so higher frequency light, such as ultraviolet light, can eject electrons with more energy than lower frequency light, such as visible light. This relationship between the **energy of the incident photons** and the **energy of the ejected electrons** is known as the photoelectric effect equation, which is given by:

$$E = W + KE$$

$$h\upsilon = W + KE$$

where KE is the energy of the ejected electron, h is Planck's constant, υ is the frequency of the incident light, and W is the work function of the metal − which is the energy required to remove an electron from the metal surface.

Here are some examples of how this equation can be used to describe the **photoelectric effect**:

**Example 1:**

Suppose a metal has a work function of 2.0 eV. What is the maximum kinetic energy of an electron ejected from the metal by light with a frequency of $6.0 \times 10^{14}$ Hz?

Using the photoelectric effect equation, we can calculate the maximum kinetic energy of the ejected electron:

$$E = h\upsilon = (6.626 \times 10^{-34}\ \text{J s}) \times (6.0 \times 10^{14}\ \text{Hz}) = 3.9756 \times 10^{-19}\ \text{J}$$

$$\text{K.E.} = E - W = (3.9756 \times 10^{-19}\ \text{J}) - (2.0\ \text{eV} \times 1.602 \times 10^{-19}\ \text{J/eV}) = 7.716 \times 10^{-20}\ \text{J}$$

Therefore, the maximum kinetic energy of the ejected electron is $7.716 \times 10^{-20}$ J

**Example 2:**

Suppose light with a frequency of $5.0 \times 10^{14}$ Hz is incident on a metal with a work function of 3.0 eV. What is the minimum frequency of light that can eject electrons from the metal?

Using the photoelectric effect equation, we can set the kinetic energy of the ejected electron to zero and solve for the minimum frequency of the incident light:

$$0 = h\upsilon - W$$

$$\upsilon = W/ h = (3.0 \text{ eV} \times 1.602 \times 10^{-19} \text{ J/eV}) / (6.626 \times 10^{-34} \text{ J s}) = 7.25324 \times 10^{14} \text{ Hz}$$

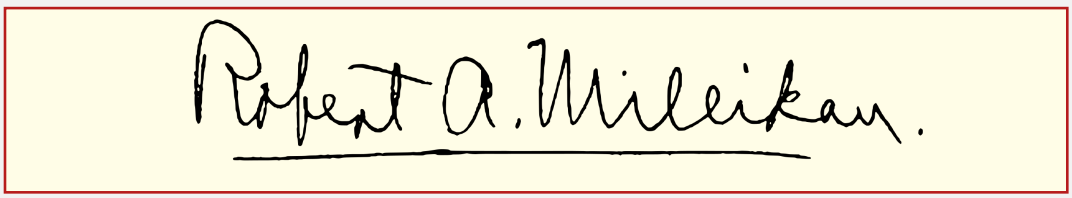
Therefore, the minimum frequency of light that can eject electrons from the metal is $7.25324 \times 10^{14}$ Hz.

These examples illustrate how the **photoelectric effect equation** can be used to calculate the kinetic energy of ejected electrons, as well as the minimum frequency of light required to eject electrons from a metal.

This theory explained several key features of the **photoelectric effect**, including why electrons were only emitted from a material surface above a certain frequency of light, known as the **threshold frequency**. Einstein's theory was initially met with skepticism, but it was later confirmed by a series of experiments, including those conducted by **Robert Millikan** in 1916, which measured the charge and mass of electrons ejected by the photoelectric effect. The discovery of the **photoelectric effect** and the subsequent development of **quantum mechanics** had a profound impact on physics and led to many important technological applications, such as the development of the **photovoltaic cell**, which is used to convert light into electrical energy. Finally, it provided support for the idea that light had both wave-like and particle-like properties, which was a key concept in the development of **quantum mechanics**. Today, the **photoelectric**

**effect** is still an active area of research, with scientists exploring new materials and applications for this fundamental phenomenon.





## Do Scientists Pray? Einstein Answers a Little Girl's Question about Science vs. Religion



A photo of Einstein in his "miracle year"

The Riverside Church

January 19, 1936

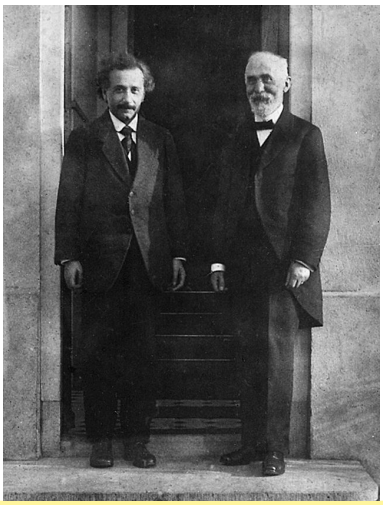
My dear Dr. Einstein,

We have brought up the question: Do scientists pray? in our Sunday school class. It began by asking whether we could believe in both science and religion. We are writing to scientists and other important men, to try and have our own question answered.

We will feel greatly honored if you will answer our question: Do scientists pray, and what do they pray for? We are in the sixth grade, Miss Ellis's class.

Respectfully yours,

Phyllis



Albert Einstein and Hendrik Antoon Lorentz, photographed by Paul Ehrenfest (1880-1933) in front of his home in Leiden in 1921.

### Einstein's reply:

January 24, 1936

Dear Phyllis,

I will attempt to reply to your question as simply as I can. Here is my answer:

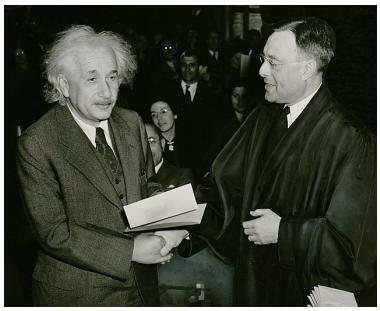
Scientists believe that every occurrence, including the affairs of human beings, is due to the laws of nature. Therefore a scientist cannot be inclined to believe that the course of events can be influenced by prayer, that is, by a supernaturally manifested wish.

However, we must concede that our actual knowledge of these forces is imperfect, so that in the end the belief in the existence of a final, ultimate spirit rests on a kind of faith. Such belief remains widespread even with the current achievements in science.

But also, everyone who is seriously involved in the pursuit of science becomes convinced that some spirit is manifest in the laws of the universe, one that is vastly superior to that of man. In this way the pursuit of science leads to a religious feeling of a special sort, which is surely quite different from the religiosity of someone more naive.

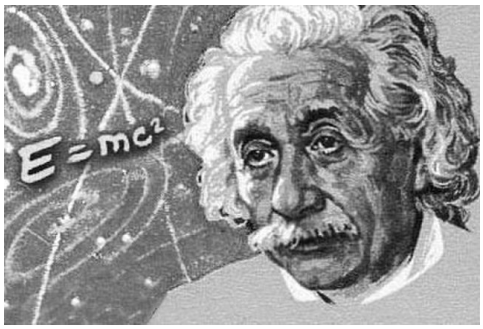
With cordial greetings,

your A. Einstein



Albert Einstein receiving from Judge Phillip Forman his certificate of American citizenship.

## ✓ Russell-Einstein Manifesto




5 April, 1955.

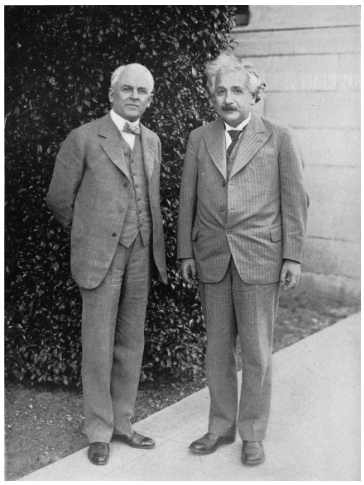
41, Queen's Road,

Richmond, Surrey.

Dear Einstein,

I have been turning over in my mind, and discussing with various people, the best steps for giving effect to the feeling against war among the great majority of men of science. I think the first step should be a statement by men of the highest eminence, communists and anti-Communists, Western and Eastern, about the disasters to be expected in a war. I enclose a draft of such a statement, and I very much hope that you will be willing to sign it. I enclose also a list of those whom I am asking to sign. If sufficient signatures are obtained, I think the next step should be an international scientific congress which should be invited by the signatories to pass a resolution on the lines of the draft resolution which I enclose. I hope that in this way both Governments and public opinion can be made aware of the seriousness of the situation.

On the whole, I have thought that it was better at this stage to approach only men of science and not men in other fields, such as Arnold Toynbee whom you mentioned. Scientists have, and feel that they have, a special responsibility, since their work has unintentionally caused our present dangers. Moreover, widening the field would make it very much more difficult to steer clear of politics.



Robert A. Millikan and Albert Einstein at the California Institute of Technology

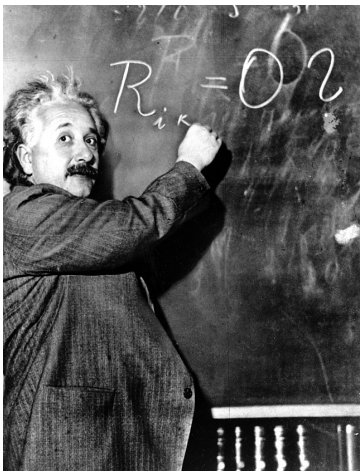
Yours sincerely,

(Signed, 'Bertrand Russell')

**✓ In response, Einstein was brief:**

Dear Bertrand Russell,

Thank you for your letter of April 5. I am gladly willing to sign your excellent statement. I also agree with your choice of the prospective signers.



Albert Einstein writes a density formula of the Milky Way on January 14, 1931 on the board of the Carnegie Institute of the Mt. Wilson Observatory in Pasadena, California.

With kind regards,

A. Einstein.

**[3] Niels Bohr**

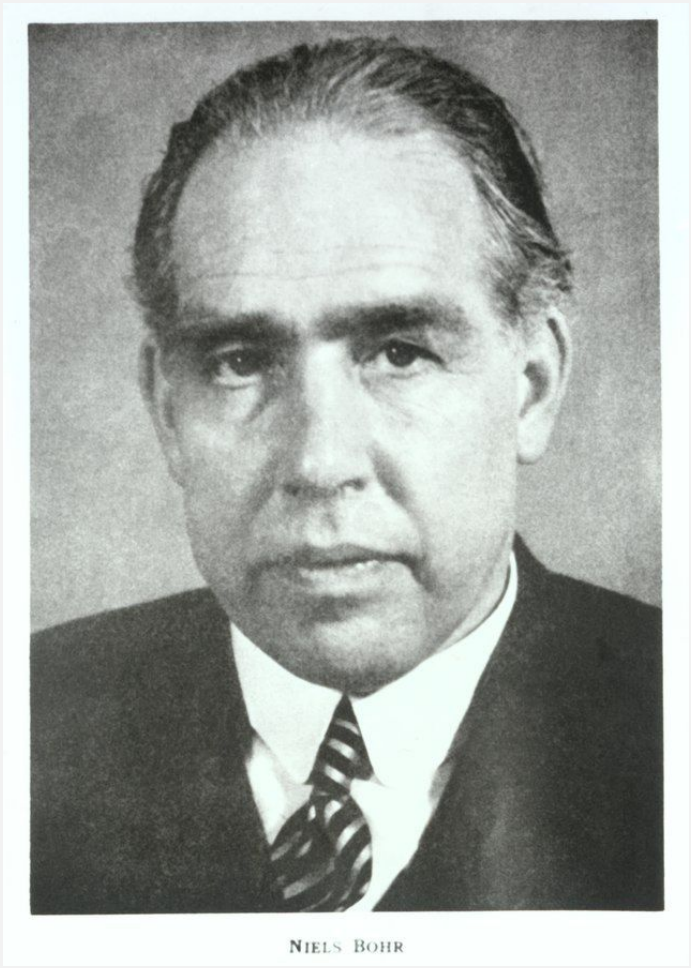
Birth: Oct. 7, 1885, Copenhagen, Denmark

Death: Nov. 18, 1962, Copenhagen

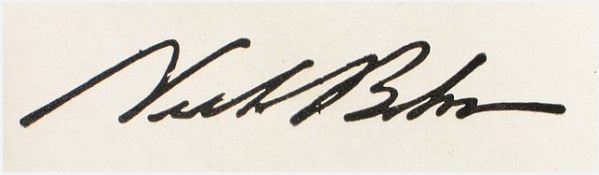
Known for: the Atom

*"Everything we call real is made of things that cannot be regarded as real."*

*— Niels Bohr*



NIELS BOHR





**Nobel Laureates in Physics Albert Einstein (left) and Niels Bohr (right) walking. Photo taken at the 1930 Solvay Conference in Brussels.**



Niels Bohr (third from left) with physics laureate Sir Chandrasekhara Venkata Raman to his right at the University of Copenhagen Institute for Theoretical Physics, 1930.



**'Tippe Top' toy demonstration by Wolfgang Pauli and Niels Bohr at the inauguration of the new Institute of Physics in Lund, Sweden**

The **Bohr atomic model** is a simplified representation of the structure of an atom proposed by Danish physicist **Niels Bohr** in 1913. The model suggests that an atom consists of a small, **dense nucleus** made up of protons and neutrons, surrounded by electrons in shells or energy levels. Each shell has a specific energy level and can only contain a certain number of electrons. When an electron absorbs or emits energy, it moves from one energy level to another. To understand the **Bohr atomic model** mathematically, we need to start with some basic concepts. The first is the idea of quantization, which suggests that certain properties of matter can only exist in discrete, quantized values. In the case of the **Bohr model**, the quantized property is the energy of an electron in an atom. The energy of an electron is related to its distance from the nucleus. The further an electron is from the nucleus, the higher its energy. The energy of an electron in an $n^{th}$ shell can be calculated using the equation:

$$E_n = \frac{-13.6eV}{n^2}$$

where –13.6 eV is a constant that represents the energy of an electron in the first shell. Using this equation, we can calculate the energy of an electron in each shell. For example, an electron in the first shell (n =1) would have an energy of $\frac{-13.6eV}{1^2}$ = –13.6 electron volts, while an electron in the second shell (n=2) would have an energy of $\frac{-13.6eV}{2^2}$ = –3.4 electron volts.

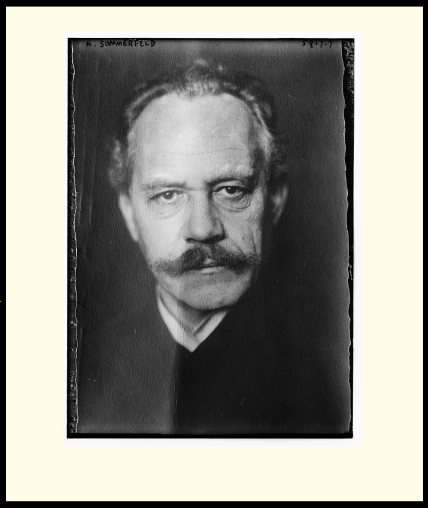
The energy of an electron can also change if it absorbs or emits energy. When an electron absorbs energy, it moves to a higher energy level (further from the nucleus), while when it emits energy, it moves to a lower energy level (closer to the nucleus). The energy absorbed or emitted can be calculated using the equation:

$$\Delta E = E_{final} - E_{initial}$$

where $\Delta E$ is the change in energy, $E_{final}$ is the energy of the electron in its final state, and $E_{initial}$ is the energy of the electron in its initial state. Using these equations, we can understand the behaviour of electrons in an atom. For example, let's consider a hydrogen atom, which has one proton in its nucleus and one electron in its outermost shell. The energy of the electron in the first shell is –13.6 eV, while the energy of the electron in the second shell is –3.4 eV. If we provide enough energy to the atom, the electron can move to the second shell (**absorbing energy equal to the difference in energy between the two shells**, $\Delta E$ = –3.4 eV – (–13.6 eV)

= 10.2 eV). If we remove energy from the atom, the electron can move back to the first shell (**emitting energy equal to the difference in energy between the two shells**, ΔE = –13.6 eV – (–3.4 eV) = –10.2 eV). The **Bohr model** provides a simplified representation of the structure of an atom and helps explain many of its properties. However, it has limitations and does not fully represent the behaviour of electrons in more complex atoms. Nonetheless, it remains an important concept in the history of atomic theory and helped pave the way for further developments in **quantum mechanics**.

Th eSommerfeld model of the atomis an extension of the earlier Bohr model, developed by the German physicist

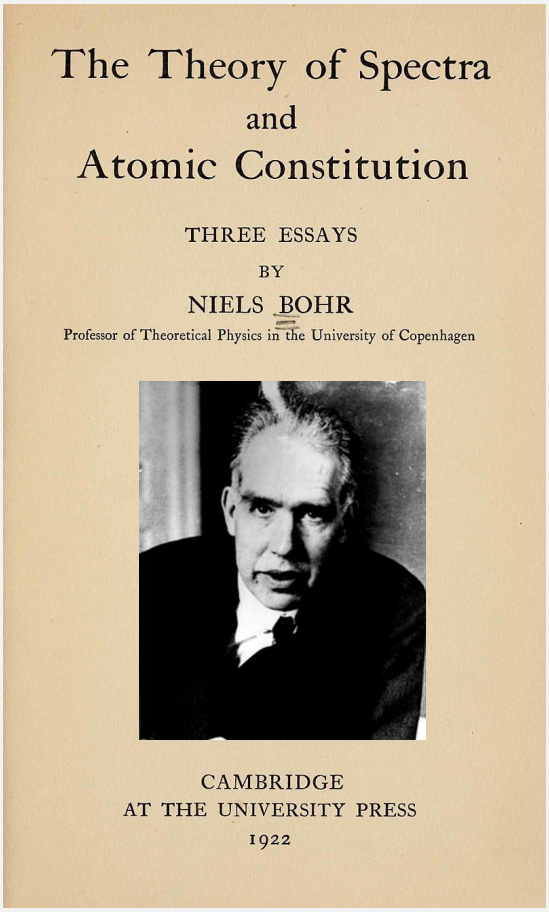


Arnold Sommerfeld in 1916. The Bohr model had successfully explained the spectra of hydrogen, but it could not explain the spectra of more complex atoms. The Sommerfeld model included several new features that addressed some of the limitations of the Bohr model. One of the key features was the introduction of elliptical orbits, which allowed for a more accurate prediction of the energy levels of electrons in more complex atoms. Sommerfeld also introduced the concept of azimuthal quantum number, which gave a more detailed description of the shape of the electron's orbit. Sommerfeld's model also included the concept of spin, which explained some of the observed properties of electrons that could not be explained by classical physics. Spin is a quantum mechanical property that gives electrons an intrinsic angular momentum. Overall, the Sommerfeld model represented a significant advance in our understanding of the atom and paved the way for further developments in quantum mechanics.

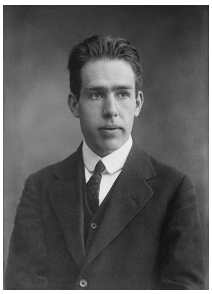


**Physicists at the Seventh Solvay Physics Conference in October 1933 in Brussels, Belgium**

The **Theory of Spectra and Atomic Constitution** is a fundamental concept in modern physics that explains the relationship between the spectral lines of atoms and their atomic structure. The theory was first proposed by **Danish physicist** **Niels Bohr** in 1913. According to the theory, atoms emit and absorb **electromagnetic radiation** only at specific wavelengths or frequencies that correspond to discrete energy levels within the atom. These energy levels are determined by the electrons orbiting the nucleus of the atom. When an electron jumps from a higher energy level to a lower one, it emits energy in the form of a photon of light, and the wavelength of the emitted photon is related to the energy difference between the two levels. The theory explains the existence of **spectral lines** in the emission and absorption spectra of atoms. Each element has a unique set of spectral lines, and the theory can be used to identify the elements present in a sample of matter based on the wavelengths of the spectral lines. The **Theory of Spectra and Atomic Constitution** is a crucial foundation for modern atomic and quantum physics, and it has led to many important discoveries and applications, including the development of lasers, nuclear energy, and quantum computing.



# Draft of letter from Bohr to Heisenberg, never sent



Bohr as a young man

**In the handwriting of Niels Bohr's assistant, Aage Petersen.**

Undated, but written after the first publication, in 1957, of the Danish translation of Robert Jungk, Heller als Tausend Sonnen, the first edition of Jungk's book to contain Heisenberg's letter



Bohr in 1922

Dear Heisenberg,

I have seen a book, "Stærkere end tusind sole" ["**Brighter than a thousand suns**"] by Robert Jungk, recently published in Danish, and I think that I owe it to you to tell you that I am greatly amazed to see how much your memory has deceived you in your letter to the author of the book, excerpts of which are printed in the Danish edition [1957].

Personally, I remember every word of our conversations, which took place on a background of extreme sorrow and tension for us here in Denmark. In particular, it made a strong impression both on Margrethe and me, and on everyone at the Institute that the two of you spoke to, that you and Weizsäcker expressed your definite conviction that Germany would win and that it was therefore quite foolish for us to maintain the hope of a different outcome of the war and to be reticent as regards all German offers of cooperation. I also remember quite clearly our conversation in my room at the Institute, where in vague terms you spoke in a manner that could only give me the firm impression that, under your leadership, everything was being done in Germany to develop atomic weapons and that you said that there was no need to talk about details since you were completely familiar with them and had spent the past two years working more or less exclusively on such preparations. I listened to this without speaking since [a] great matter for mankind was at issue in which, despite our personal friendship, we had to be regarded as representatives of two sides engaged in mortal combat. That my silence and gravity, as you write in the letter, could be taken as an expression of shock at your reports that it was possible to make an atomic bomb is a quite peculiar misunderstanding, which must be due to the great tension in your own mind. From the day three years earlier when I realized that slow neutrons could only cause fission in Uranium 235 and not 238, it was of course obvious to me that a bomb with certain effect could be produced by separating the uraniums. In June 1939 I had even given a public lecture in Birmingham about uranium fission, where I talked about the effects of such a bomb but of course added that the technical preparations would be so large that one did not know how soon they could be overcome. If anything in my behaviour could be interpreted as shock, it did not derive from such reports but rather from the news, as I had to understand it, that Germany was participating vigorously in a race to be the first with atomic weapons.

Besides, at the time I knew nothing about how far one had already come in England and America, which I learned only the following year when I was able to go to England after being informed that the German occupation force in Denmark had made preparations for my arrest.

All this is of course just a rendition of what I remember clearly from our conversations, which subsequently were naturally the subject of thorough discussions at the Institute and with other trusted friends in Denmark. It is quite another matter that, at that time and ever since, I have always had the definite impression that you and Weizsäcker had arranged the symposium at the German Institute, in which I did not take part myself as a matter of principle, and the visit to us in order to assure yourselves that we suffered no harm and to try in every way to help us in our dangerous situation.

This letter is essentially just between the two of us, but because of the stir the book has already caused in **Danish newspapers**, I have thought it appropriate to relate the contents of the letter in confidence to the head of the Danish Foreign Office and to Ambassador Duckwitz.



Werner Heisenberg (left) with Bohr at the Copenhagen Conference in 1934

### [4] Charles Darwin

Birth: Feb. 12, 1809, Shrewsbury, Shropshire, England

Death: April 19, 1882, Downe, Kent

Known for: Evolution

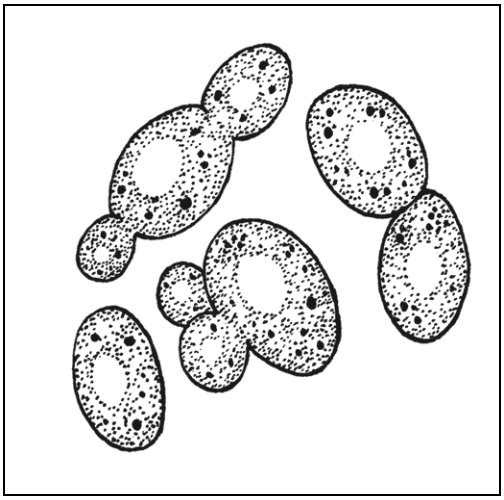
> *"If I had my life to live over again, I would have made a rule to read some poetry and listen to some music at least once every week."*
>
> *— Charles Darwin*

**We do share approximately 90% of our DNA with chimpanzees.**

✓ **The first mammal to descend from reptiles was the platypus.**

**The term "survival of the fittest" was not coined by Charles Darwin (1809–1882) to sum up his thesis. The phrase was instead established by the philosopher Herbert Spencer (1820–1903).**

**Yeast, a single live cell that repeats every 90 minutes, and humans have approximately 31% of the same genes.**

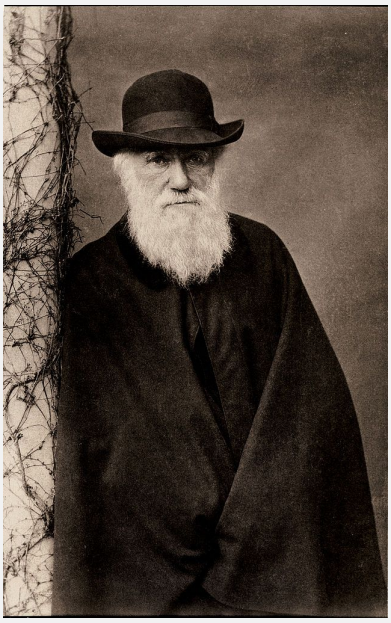


**The term "evolution" does not occur in Charles Darwin's book "On the Origin of Species" (1859), despite the fact that it is the book from which the modern theory of evolution originated.**

The word "evolution" comes from the Latin evolutionem, which is used to describe the unrolling or unfolding of something that has been coiled up.

The three fundamental assumptions of the theory of evolution are as follows:

1) It is plausible for an organism's DNA to alter or mutate
2) The change may be detrimental, constructive, or neutral
3) Over an extended period of time, the mutations result in the emergence of new organisms.



**Charles Darwin as an old man**



**Charles Darwin at age six, with his Sister Catherine, in an 1816 chalk sketch**

**Evolution** is the process by which populations of organisms change over time. There are several principles of **evolution** that describe how this process occurs:





## 1. Variation:

Within a population, there is genetic variation, meaning that individuals have different traits due to differences in their DNA.

## 2. Inheritance:

These genetic differences can be passed down from parent to offspring, leading to variation within the next generation.

## 3. Selection:

Some individuals are better adapted to their environment than others and are more likely to survive and reproduce. This process is called natural selection.

## 4. Differential Reproduction:

Individuals that are more successful in reproducing are more likely to pass on their genes to the next generation.

## 5. Speciation:

Over time, genetic differences between populations can accumulate to the point where they become distinct species.

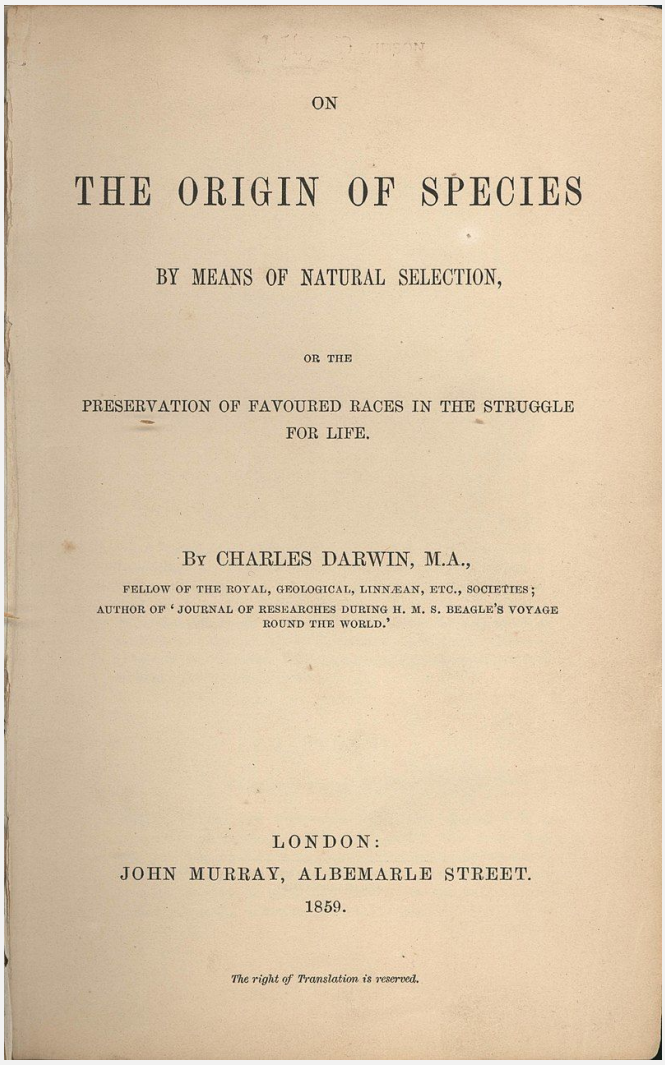
## 6. Gradualism:

Evolution occurs gradually over long periods of time through the accumulation of small changes.

## 7. Common Descent:

All living organisms share a common ancestor, and the diversity of life on Earth can be explained by a branching pattern of descent from this ancestor.

These principles of **evolution** help to explain the diversity of life on Earth and how organisms have adapted to their environments over time.



ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

By CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

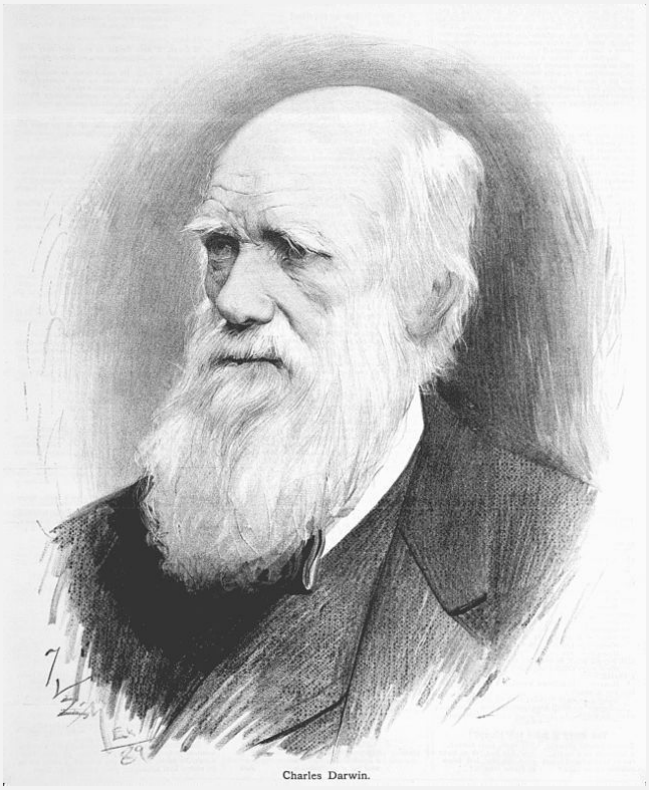
*The right of Translation is reserved.*




**The Origin of Species** is a book written by **Charles Darwin** and first published in 1859. In this book, **Darwin** presented his **theory of evolution** by **natural selection**, which is now widely accepted as the basis for modern evolutionary theory. **Darwin's theory** proposes that all **species of life** have descended over time from common ancestors through the process of natural selection. This means that individuals within a species vary in their **inherited traits**, and those individuals with traits better suited to their environment are more likely to survive and reproduce. Over time, this results in the accumulation of **favorable traits** in a population, leading to the development of new species. **Darwin's theory** challenged the religious beliefs, particularly those related to the creation story in the **Bible**, and it revolutionized the way that people thought about the natural world. **The Origin of Species** is widely regarded as one of the most important scientific works ever published, and it continues to influence the fields of biology, geology, anthropology, and philosophy today.



**Darwin in 1842 with his eldest son, William Erasmus Darwin**



Charles Darwin.



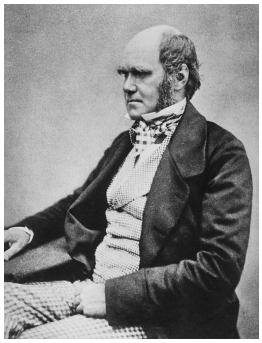


## ✓ Darwin-Hooker Letter

"At last gleams of light have come, & I am almost convinced (quite contrary to opinion I started with) that species are not (it is like confessing a murder) immutable."

**Charles Darwin to Joseph Dalton Hooker, 11 January 1844**

## ✓ A letter to Charles Darwin from Jerry Coyne



Darwin, c. 1854, when he was preparing On the Origin of Species for publication

My Dear Mr. Darwin,

Happy 200th birthday! I hope you are as well as can expected for someone who has been dead for nearly 130 years. I suppose that your final book, the one about earthworms, has a special significance for you these days. Are the worms of Westminster Abbey superior to the ones you studied so carefully in the grounds of your home at Downe in Kent? They've certainly mulched some distinguished people over the years!

But enough of the personal questions: let me introduce myself. I am one of thousands – maybe tens of thousands – of professional biologists who work full time on your scientific legacy. You'll be happy to know that Britain remains a powerhouse in what we nowadays call evolutionary biology, and your ideas now have wide currency across the entire planet. I work in Chicago, in the United States of America. But even the French have finally reluctantly relinquished their embrace of Jean-Baptiste Lamarck, whose misguided evolutionary ideas you did so much to discredit.

Your Origin of Species turns 150 this year. I just re-read it in your honour and must say that, though you did not always have the snappiest turn of phrase, it really is a wonderfully comprehensive and insightful work. It is remarkable, considering what you did not know when you wrote it, how robust the book has proved over the years. The findings of modern biology, many of them inconceivable to you as you beavered away in your Down House study, have provided ever more evidence in support of your ideas, and none that contradicts them. We have learned a huge amount in the past 150 years, but nearly all of it still fits comfortably into the framework you outlined in The

Origin. Take DNA, for example. This is what we call the hereditary material that is passed down from generation to generation. You knew nothing about it – remember how you wished you understood more about how heredity works? Now we have full DNA sequences from dozens of species, each one a string of billions of the four DNA letters — A, T, G and C — each a different chemical compound. What do we find when we compare these sequences, say between a mouse and a human? We see the DNA equivalent of the anatomical similarities – as mammals – that you noted mice and humans share because they are descended from a common ancestor, an early mammal. Strings of As, Gs, Cs, and Ts tell precisely the same evolutionary story as traits like lactation and warm-bloodedness. It is absolutely marvelous that your 150 year old insight on common ancestry should be so relevant to the very latest discoveries of the new field we call molecular biology.

In The Origin, you gave very little evidence for evolution from the fossil record, wringing your hands instead about the incompleteness of the geological record. But since then, the labors of fossil-hunters throughout the world have turned up plenty of evidence of evolutionary change, and many amazing "transitional" forms that connect major groups of animals, proving your idea of common ancestry. You predicted that these forms would exist; we have found them. These include fossils that show transitions between mammals and reptiles, fish and amphibians, and even dinosaurs with feathers—the ancestors of birds! Just in the past few years, paleontologists have unearthed an astonishing fossil, called Tiktaalik, that is intermediate between fish and amphibians. It has the flat head and neck of an amphibian, but a fishy tail and body, while its fins are sturdy, easily able, with slight modification, to give them a leg up when they left the water. The fossil record has given us a direct glimpse of an event of great moment in the history of the planet: the colonization of land by vertebrates. And we have evidence just as convincing for the recolonization of the sea by mammals: the group that gave rise to whales. In The Origin, you were correct in suggesting that whales arose from land animals, but you got it wrong on one point. You thought they may have come from carnivores like bears, but we now know this is not true. Instead, the ancestral whale came from a small hooved animal rather like a deer. And in the last thirty years we have discovered a whole series of intermediate fossils spanning the gap from those ancient deer to modern whales, showing them losing their hind legs, evolving flippers, and moving their breathing hole to the top of their head. Both Tiktaalik and these ancestral whales put paid to the objection, which you yourself encountered, that no transitional form between land and water could possibly have existed.

Perhaps the most remarkable set of intermediate fossils, however, come from an evolutionary transition rather closer to home. In 1871, you more predicted that, since humans seem most related to African great apes, gorillas and chimpanzees, we would find human fossils on that continent. And now we have them—in profusion! It turns out that our lineage separated from that of chimpanzees, our closest living relatives, nearly 7 million years ago, and we have a superb series of fossils documenting our transition from early apelike creatures to more modern human forms. Our own species has become an exemplar of evolution. And we know even more: evidence from our hereditary DNA

material has told us that all modern humans came from a relatively recent migration event—about 100,000 years ago—when our ancestors left Africa and spread throughout the world.

The idea you were proudest of was natural selection. That too has had a good 150 years, holding up well as the main cause of evolution and the only known cause of adaptation. Perhaps the most dramatic modern example involves bacteria that are now known to cause disease, including the scarlet fever that was such a plague upon your family. Chemists have developed drugs to cure diseases like this, but now, as you might well predict, the microbes are becoming resistant to those drugs—precisely in accord with the principles of natural selection—for the most drug-resistant microbes are the ones that survive to breed. There are hundreds of other cases. One that will especially please you is the observation of natural selection in the Galápagos finches you collected in the Beagle voyage—now called "Darwin's finches" in your honor. A few decades ago, zoologists observed a great drought on the islands that reduced the number of small seeds available for the birds to eat. And, just as predicted, natural selection caused the evolution of larger-beaked birds within only a few years. These examples would surely be a centerpiece of The Origin were you to rewrite it today.

All told, the resilience of your ideas is remarkable. But that is not to say that you got everything right. On The Origin of Species was, admit it, a misnomer. You described correctly how a single species changes through time, but you came a cropper trying to explain how one species splits into two. Speciation is a significant problem, because it underpins the branching process that has yielded the tree of life – that extraordinary vision you bequeathed us of the natural world as one vast genealogy. Speciation is the key to understanding how, starting with the very first species on earth, evolution has resulted in the 50 million species that are thought to inhabit our planet today.

You once called speciation the "mystery of mysteries," but it’s a lot less mysterious these days. We recognize now that species are separated one from another by barriers to reproduction. That is, we recognize different species, like humans and chimpanzees, because they cannot successfully interbreed. To modern evolutionary biologists, studying "the origin of species" means studying how these barriers to reproduction arise. And now that we have a concrete phenomenon to investigate, we are making remarkable progress in understanding the genetic details of how one species splits into two. This is in fact the problem to which I’ve devoted my entire career

I wish I could end this letter by telling you that your theory of evolution has achieved universal acceptance. As you well knew, evolution has proved a bitter pill for religious people to swallow. For example, a large proportion of the American public, despite access to education, clings to a belief in the literal truth of Genesis. You will find this hard

to believe, but more Americans believe in the existence of heavenly angels than accept the fact of evolution. Unfortunately, I must often put aside my research to fight the attempts of these "creationists" to have their Biblical views taught in the public schools. Humans have evolved extraordinary intellectual abilities, but sadly these are not always given a free rein by their owners. But this probably won't surprise you – remember the Bishop of Oxford and his attempt to put your friend Thomas H. Huxley in his place?

**You wrote in your introduction to The Origin of Species that**

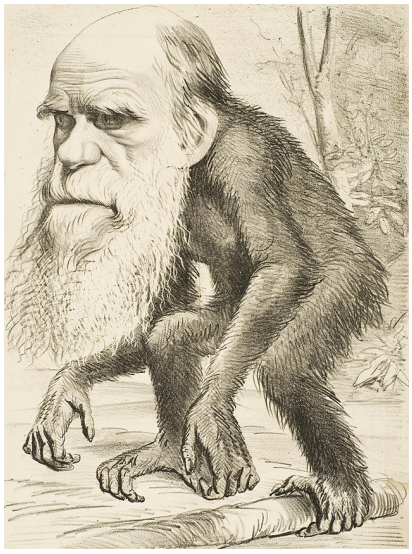
> "No one can feel more sensible than I do of the necessity of hereafter publishing in detail all the facts, with references, on which my conclusions have been grounded; and I hope in a future work to do this."

It seems that, distracted by other projects, you never got around to it, but my own effort along these lines is represented in a book (which I enclose) called Why Evolution is True. It goes further to describe the evidence supporting you than a letter this size ever could, but it's just one book at just one moment in the history of biology. When I myself am as long gone as you are, somebody else will certainly need to write an update, for the facts supporting your theories continue to roll in, and I wager they will continue to do so.

So, rest in peace, Mr. Darwin, and here's hoping that the next hundred years will see a steady evolution of rationality in a troubled world.

Your most humble servant,

Jerry Coyne



Editorial cartoon depicting Charles Darwin as an ape (1871)

## [5] Louis Pasteur

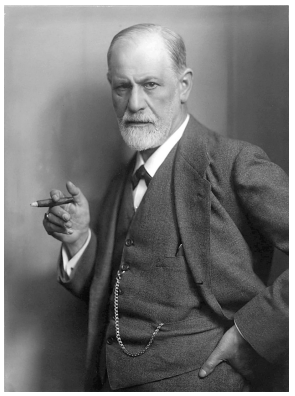
Birth: Dec. 27, 1822, Dole, France

Sept. 28, 1895, Saint-Cloud, near Paris

Known for: the Germ Theory of Disease

*"Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world."*

*— Louis Pasteur*



**[6] Sigmund Freud**

Birth: May 6, 1856, Freiberg, Moravia, Austrian Empire [now Přibor, Czech Republic]

Death: Sept. 23, 1939, London, England

Known for: Psychology of the Unconscious

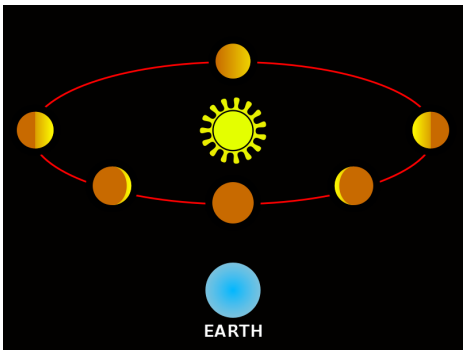
*"Religion is an attempt to get control over the sensory world, in which we are placed, by means of the wish-world, which we have developed inside us as a result of biological and psychological necessities. But it cannot achieve its end. Its doctrines carry with them the stamp of the times in which they originated, the ignorant childhood days of the human race. Its consolations deserve no trust. Experience teaches us that the world is not a nursery. The ethical commands, to which religion seeks to lend its weight, require some other foundations instead, for human society cannot do without them, and it is dangerous to link up obedience to them with religious belief. If one attempts to assign to religion its place in man's evolution, it seems not so much to be a lasting acquisition, as a parallel to the neurosis which the civilized individual must pass through on his way from childhood to maturity."*

*— Sigmund Freud*

**[7] Galileo Galilei**

Birth: Feb. 15, 1564, Pisa [Italy]

Death: Jan. 8, 1642, Arcetri, near Florence




The phases of Venus, observed by Galileo in 1610

Known for: the New Science

> *"In questions of science, the authority of a thousand is not worth the humble reasoning of a single individual."*
>
> *— Galileo Galilei*



Galileo showing the Doge of Venice how to use the telescope

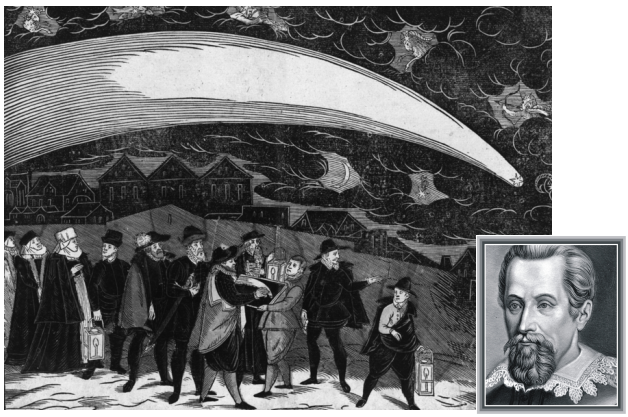
**[8] Antoine-Lau rent Lavoisier**

Birth: Aug. 26, 1743, Paris, France

Death: May 8, 1794, Paris

Known for: the Revolution in Chemistry

> *"In nature nothing is created, nothing is lost, everything changes."*
>
> *— Antoine-Laurent de Lavoisier*



As a child, Kepler witnessed the Great Comet of 1577, which attracted the attention of astronomers across Europe.

**[9] Johannes Kepler**

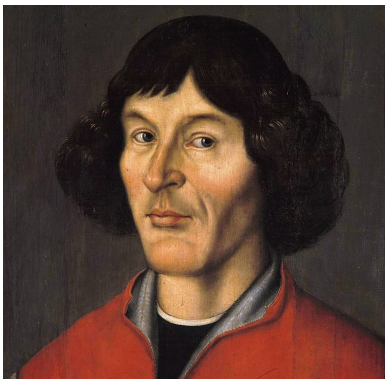
Birth: Dec. 27, 1571, Weil der Stadt, Wurttemberg [Germany]

Death: Nov. 15, 1630, Regensburg

Known for: Motion of the Planets

> *"Geometry has two great treasures; one is the Theorem of **Pythagoras**; the other, the division of a line into extreme and mean ratio. The first we may compare to a measure of gold; the second we may name a precious jewel."*

— *Johannes Kepler*



**[10] Nicolaus Copernicus**

Birth: Feb. 19, 1473, Toruń, Poland

Death: May 24, 1543, Frauenburg, East Prussia [now Frombork, Poland]

Known for: the Heliocentric Universe



*"To know that we know what we know, and to know that we do not know what we do not know, that is true knowledge."*

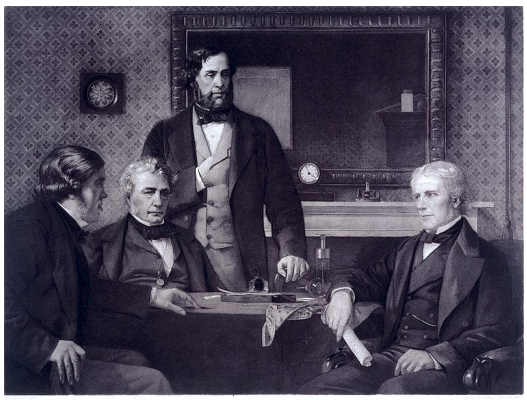
— *Nicolaus Copernicus*

**[11] Michael Faraday**

Birth: Sept. 22, 1791, Newington, Surrey, England

Death: Aug. 25, 1867, Hampton Court

Known for: the Classical Field Theory



Three Fellows of the Royal Society offering the presidency to Faraday, 1857

*"Nothing is too wonderful to be true if it be consistent with the laws of nature."*

— *Michael Faraday*

**[12] James Clerk Maxwell**

Birth: June 13, 1831, Edinburgh, Scotland

Death: Nov. 5, 1879, Cambridge, Cambridgeshire, England



Faraday holding a type of glass bar he used in 1845 to show magnetism affects light in dielectric material.

Known for: the Electromagnetic Field

> *"Thoroughly conscious ignorance is the prelude to every real advance in science."*
>
> *— James Clerk Maxwell*



J. Clerk Maxwell

## ✓ Maxwell Letter to R. B. Litchfield

5 February 1858, from The Life of James Clerk Maxwell, Campbell and Garnett, pp.306-6

With respect to the " material sciences," they appear to me to be the appointed road to all scientific truth, whether metaphysical, mental, or social. The knowledge which exists in these subjects derives a great part of its value from ideas suggested by analogies from the material sciences, and the remaining part, though valuable and important to mankind, is not scientific but aphoristic. The chief philosophical value of physics is that it gives the mind something distinct to lay hold of, which, if you don't, Nature at once tells you you are wrong. Now, every stage of this conquest of truth leaves a more or less presentable trace on the memory, so that materials are furnished here more than anywhere else for investigation of the great question, "How does Knowledge come?"

I have observed that the practical cultivators of science (e.g., Sir J. Herschel, Faraday, Ampere, Oersted, Newton, Young), although differing excessively in turn of mind, have all a distinctness and a freedom from the tyranny of words in dealing with questions of Order, Law, etc., which pure speculators and literary men never attain.

Now, I am going to put down something on my own authority, which you must not take for more than it is worth. There are certain men who write books, who assume that, whatever things are orderly, certain, and capable of being accurately predicted by men of experience, belong to one category; and whatever things are the result of conscious action, whatever are capricious, contingent, and cannot be foreseen, belong to another category.

All the time I have lived and thought, I have seen more and more reason to disagree with this opinion, and to hold that all want of order, caprice, and unaccountableness results from interference with liberty, which would, if unimpeded, result in order, certainty, and trustworthiness (certainty of success of predicting). Remember I do not say that caprice and order are not the result of free will (so called), only I say that there is a liberty which is not disorder, and that this is by no means less free than the other, but more.

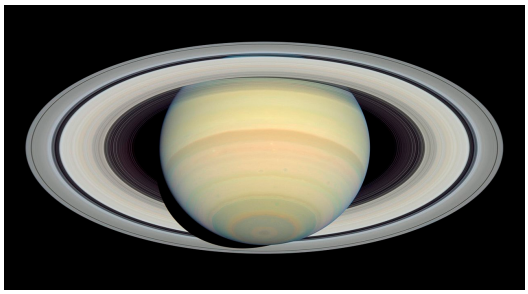
In the next place, there are various states of mind, and schools of philosophy corresponding to various stages in the evolution of the idea of liberty.

In one phase, human actions are the resultant (by parallelogram of forces) of the various attractions of surrounding things, modified in some degree by internal states, regarding which all that is to be said is that they are subjectively capricious, objectively the "RESULT OF LAW," — that is, the wilfulness of our wills feels to us like liberty, being in reality necessity.

In another phase, the wilfulness is seen to be anything but free will, since it is merely a submission to the strongest attraction, after the fashion of material things. So some say that a man's will is the root of all evil in him, and that he should mortify it out till nothing of himself remains, and the man and his selfishness disappear together. So said Buddha (see Max Muller), and many Christians have and thought nearly the same thing.

Nevertheless there is another phase still, in which appears a possibility of the exact contrary to the first state, namely, an abandonment of wilfulness without extinction of will, but rather by means of a great development of will, whereby, instead of being consciously free and really in subjection to unknown laws, it becomes consciously acting by law, and really free from the interference of unrecognised laws.

There is a screed of metaphysics. I don't suppose that is what you wanted. I have no nostrum that is exactly what you want. Every man must brew his own, or at least fill his own glass for himself, but I greatly desire to hear some more from you, just to get into rapport.





**Maxwell proved that the Rings of Saturn were made of numerous small particles.**

### [13] Claude Bernard

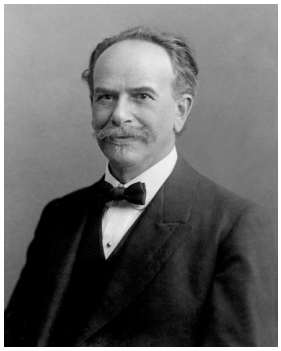
Birth: July 12, 1813, Saint-Julien

Death: February. 10, 1878, Paris

Known for: the Founding of Modern Physiology

> *"Man can learn nothing except by going from the known to the unknown."*
>
> *— Claude Bernard*

### [14] Franz Boas



Birth: July 9, 1858, Minden, Westphalia, Germany

Death: December 21, 1942, New York, U.S

Known for: Modern Anthropology



> *"The passion for seeking the truth for truth's sake...can be kept alive only if we continue to seek the truth for truth's sake."*
>
> *— Franz Boas*

**[15] Werner Heisenberg**



Birth: December, 1901, Würzburg, Bavaria, German Empire

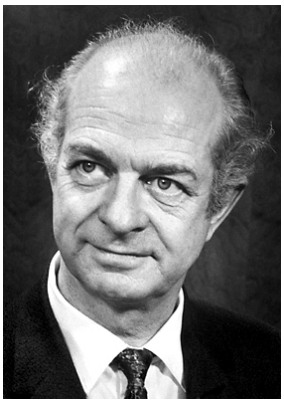
Death: 1 February 1976, Munich, Bavaria, West Germany

Known for: Quantum Theory



> *"What we observe is not nature itself, but nature exposed to our method of questioning."*
>
> *— Werner Heisenberg*

**[16] Linus Pauling**



Birth: Feb. 28, 1901, Portland, Ore., U.S.

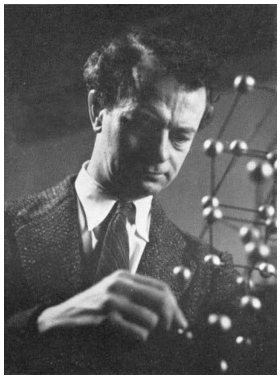
Death: Aug. 19, 1994, Big Sur, California

Known for: Twentieth-Century Chemistry

Linus Pauling, 1952

*"The best way to get a good idea is to have a lot of ideas."*

*— Linus Pauling*



**Linus Pauling at the California Institute of Technology (1941)**

**✓ Letter from Linus Pauling to President Kennedy**

**(April 29, 1962: Paulings Protest Nuclear Testing)**

1 March 1962 Night Letters Durham, NC

President John F. Kennedy, White House:

Are you going to give an order that will cause you to go down in history as one of the most immoral men of all time and one of the greatest enemies of the human race? In a letter to the New York Times, I state that nuclear tests duplicating the Soviet 1961 tests would seriously damage over 20 million unborn children, including those caused to have gross physical or mental defect and also the still births and embryonic, neonatal and childhood deaths from the radioactive fission products and carbon 14. Are you going to be guilty of this monstrous immorality, matching that of the Soviet leaders, for the political purpose of increasing the still imposing lead of the United States over the Soviet Union in nuclear weapons technology?

(Signed) Linus Pauling





**[17] Erwin Schrodinger**

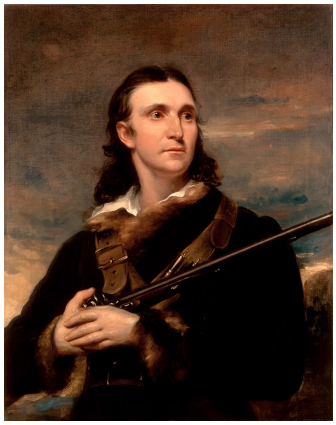
Birth: Aug. 12, 1887, Vienna, Austria

Death: Jan. 4, 1961, Vienna

Known for: Wave Mechanics

*"The scientist only imposes two things, namely truth and sincerity, imposes them upon himself and upon other scientists."*

— *Erwin Schrödinger*



**[18] John James Audubon**

Birth: April 26, 1785, Les Cayes, Saint-Domingue, West Indies [now in Haiti]

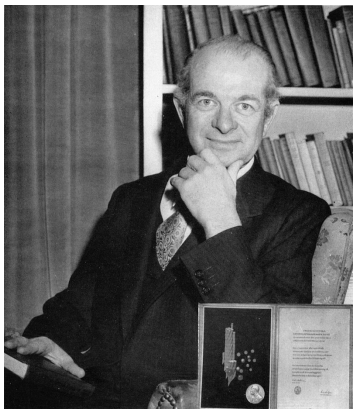
Death: Jan. 27, 1851, New York, N.Y., U.S.

Known for: drawings and paintings of North American birds



*"The woods would be very silent if no birds sang except those who sang the best."*

— *John James Audubon*



**[19] Ernest Rutherford**

Birth: Aug. 30, 1871, Spring Grove, N.Z.

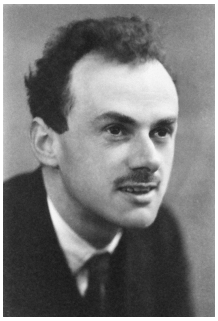
Death: Oct. 19, 1937, Cambridge, Cambridgeshire, England

Known for: the Structure of the Atom

**Linus Pauling with an inset of his Nobel Prize in 1955**

*"All science is either physics or stamp collecting."*

— *Ernest Rutherford*



**[20] Paul Adrien Maurice Dirac**

Birth: Aug. 8, 1902, Bristol, Gloucestershire, England

Death: Oct. 20, 1984, Tallahassee, Florida, USA

**Dirac, photographed in 1933**

Known for: Quantum Electrodynamics

> *"A theory with mathematical beauty is more likely to be correct than an ugly one that fits some experimental data. God is a mathematician of a very high order, and He used very advanced mathematics in constructing the universe."*
>
> *— Paul A. M. Dirac*

**[21] Andreas Vesalius**

Birth: Dec. 1514, Brussels [now in Belgium]

Death: June 1564, island of Zacynthus, Republic of Venice [now in Greece]

Known for: the New Anatomy




USSR stamp: Ernest Rutherford and Diagram of Rutherford Scattering

> *"I am not accustomed to saying anything with certainty after only one or two observations."*
>
> *— Andreas Vesalius*

**[22] Tycho Brahe**

Birth: Dec. 14, 1546, Knudstrup, Scania, Denmark

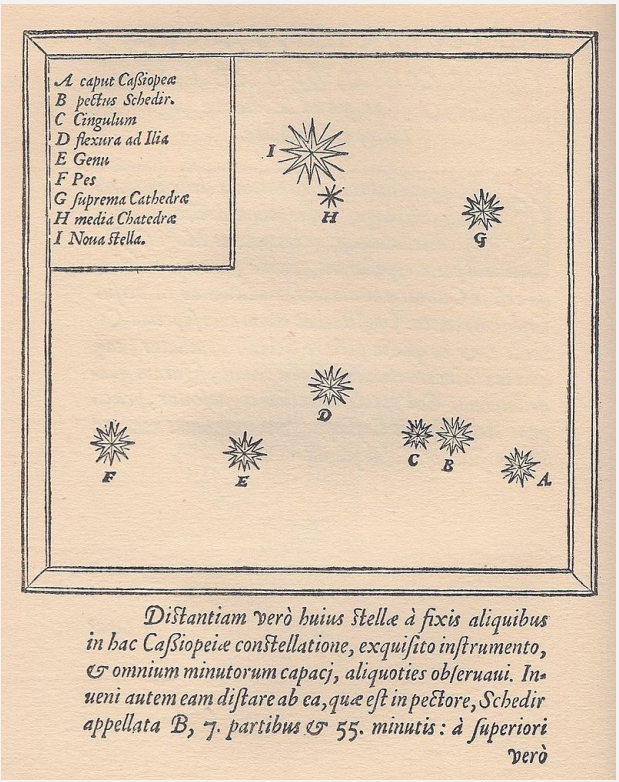
Death: Oct. 24, 1601, Prague

Known for: the New Astronomy



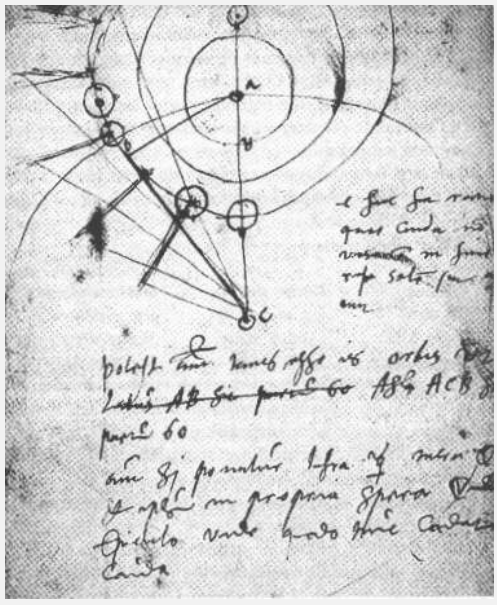
Tycho Brahe

> *"Let me not seem to have lived in vain."*
>
> *— Tycho Brahe*




Star map of the **Cassiopeia constellation** illustrating the location of the supernova of 1572 (the topmost star, labelled I); from **Tycho Brahe's De nova stella**.



**Brahe's notebook with his observations of the 1577 comet**



**[23] Comte de Buffon**

Birth: September 07, 1707, Montbard, Burgundy, France

Death: April 16, 1788, Paris, France

Known for: l'Histoire Naturelle



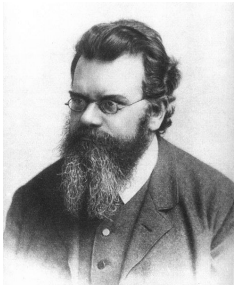
> *"Genius is nothing but a great aptitude for patience."*
>
> *— Comte Georges-Louis Leclerc de Buffon*

**[24] Ludwig Boltzmann**

Birth: February 20, 1844, Vienna, Austrian Empire (present-day Austria)

Death: September 5, 1906, Tybein near Trieste, Austria-Hungary [present-day Duino, Italy]

Known for: Thermodynamics





> *"Available energy is the main object at stake in the struggle for existence and the evolution of the world."*
>
> *— Ludwig Boltzmann*

- Tragic deaths in science: Ludwig Boltzmann — a mind in disorder. Can a life be summed up by

$$S = k_B \ln W ?$$

The equation is the slightly geeky inscription on the tombstone of Ludwig Boltzmann, Austrian physicist and pioneer of statistical mechanics.

The formula " $S = k_B \ln W$ " is known as the **Boltzmann entropy formula**, where S represents the entropy of a system, $k_B$ is the **Boltzmann constant**, and W is the number of microstates available to the system. **For example,** consider a gas in a container. The molecules in the gas can move around in different ways, which means that there are many different possible arrangements or microstates of the molecules. The entropy of the gas can be calculated using the **Boltzmann entropy formula**. Let's say that the gas has 10 molecules and can occupy 50 different positions within the container. The number of microstates available to the system is:

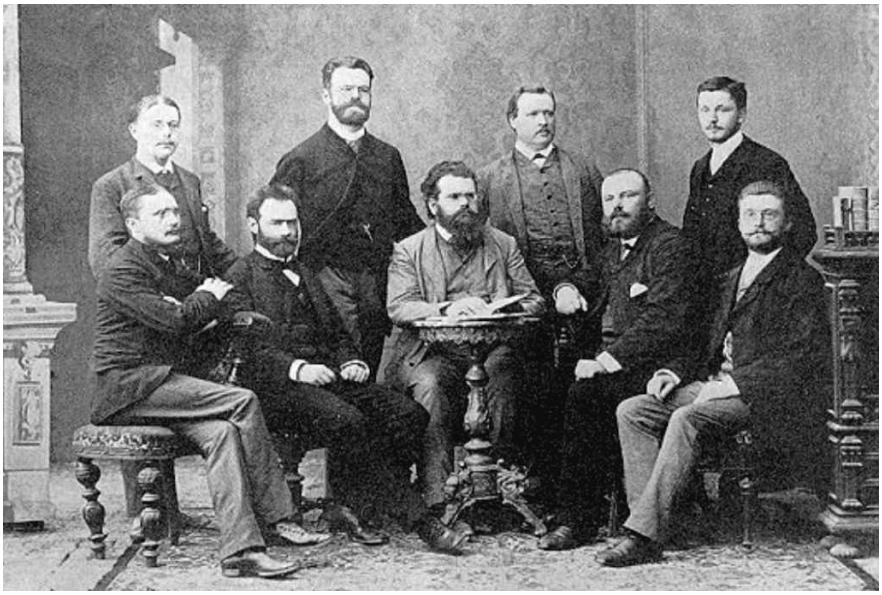
$$W = (50)^{10}$$

Using the Boltzmann constant, $k_B = 1.38 \times 10^{-23}$ J/K, the entropy of the system can be calculated as:

$$S = k_B \ln W = 1.38 \times 10^{-23} \text{ J/K} \times \ln [(50)^{10}]$$

$$S = 1.38 \times 10^{-23} \text{ J/K} \times 10 \times \ln (50) \approx 5.39 \times 10^{-22} \text{ J/K}$$

Therefore, the entropy of the gas in the container is approximately $5.39 \times 10^{-22}$ J/K.



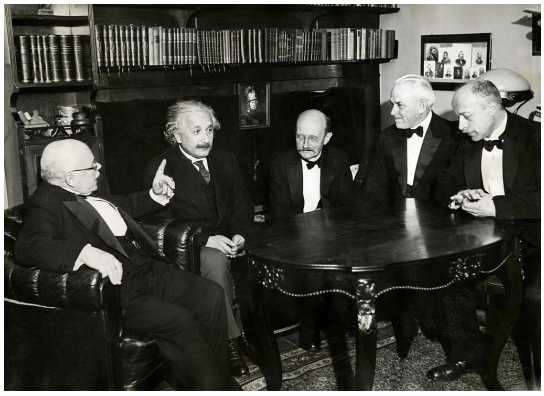
**Ludwig Boltzmann and co-workers in Graz, 1887:** (standing, from the left) Nernst, Streintz, Arrhenius, Hiecke, (sitting, from the left) Aulinger, Ettingshausen, Boltzmann, Klemenčič, Hausmanninger

## [25] Max Planck

Birth: April 23, 1858, Kiel, Schleswig [Germany]

Death: Oct. 4, 1947, Göttingen, West Germany

Known for: the Quanta

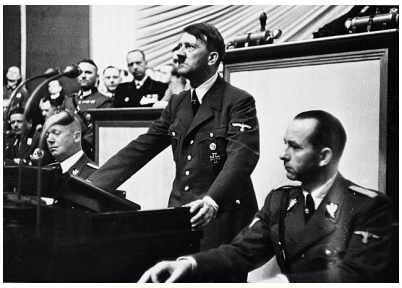


From left to right: W. Nernst, A. Einstein, Planck, R.A. Millikan and von Laue at a dinner given by von Laue in Berlin on 11 November 1931

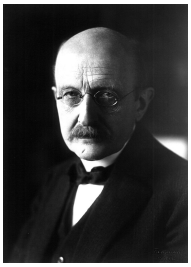
> *"Science cannot solve the ultimate mystery of nature. And that is because, in the last analysis, we ourselves are a part of the mystery that we are trying to solve."*
>
> *— Max Planck*

- Sadly Planck life was filled with tragedy in the years following his remarkable initiation of the study of **quantum mechanics.**

### ✓ Max Planck Letter to Hitler



Adolf Hitler



Planck in 1930

"My Führer!

I am most deeply shaken by the message that my son Erwin has been sentenced to death by the People's Court.

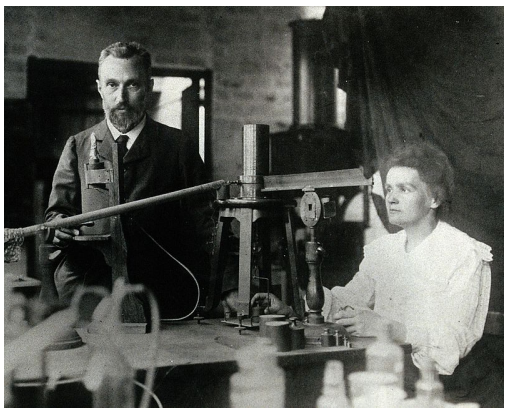
The acknowledgement for my achievements in service of our fatherland, which you, my Führer, have expressed towards me in repeated and most honouring way, makes me confident that you will lend your ear to an imploring 87-year old.

As the gratitude of the German people for my life's work, which has become an everlasting intellectual wealth of Germany, I am pleading for my son's life.

Max Planck"

## [26] Marie Curie

Birth: Nov. 7, 1867, Warsaw, Poland, Russian Empire



Pierre and Marie Curie in the laboratory, c. 1904



Death: July 4, 1934, near Sallanches, France

Known for: Radioactivity

*"Be less curious about people and more curious about ideas."*

*— Marie Curie*

**Marie Curie** was a Polish-French physicist and chemist who, together with her husband Pierre Curie, conducted pioneering research in radioactivity. In 1903, they were awarded the Nobel Prize in Physics for their work on the radiation phenomena discovered by **Henri Becquerel**. **Marie Curie** became the first woman to win a **Nobel Prize**, and she was also the first person to win it twice when she was awarded the **Nobel Prize in Chemistry** in 1911 for her discovery of the elements radium and polonium.



Marie and daughter Irène, 1925

### [27] Sir William Herschel

Birth: Nov. 15, 1738, Hanover, Germany

Death: Aug. 25, 1822, Slough, Buckinghamshire, England

Known for: Sidereal astronomy

*"An object is frequently not seen from not knowing how to see it, rather than from any deficit in the organ of vision. I will instruct you how to see them..."*

*— William Herschel*



Charles Lyell at the British Association meeting in Glasgow 1840.

### [28] Charles Lyell

Birth: Nov. 14, 1797, Kinnordy, Forfarshire, Scotland

Death: Feb. 22, 1875, London, England

Known for: Modern Geology

*"Geology is intimately related to almost all the physical sciences, as history is to the moral. An"*

*— Charles Lyell*



**[29] Pierre Simon de Laplace**

Birth: March 23, 1749, Beaumount-en-Auge, Normandy, France

Death: March 5, 1827, Paris

Known for: Black hole, nebular hypothesis of the origin of the solar system



*"Your Excellency, I have no need of this hypothesis."*

*— Pierre Laplace*

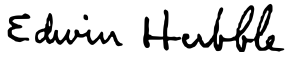


**[30] Edwin Powell Hubble**

Birth: Nov. 20, 1889, Marshfield, Mo., U.S.

Death: Sept. 28, 1953, San Marino, California

Known for: Extragalactic astronomy



*"Science is the one human activity that is truly progressive. The body of positive knowledge is transmitted from generation to generation."*

*— Edwin Powell Hubble*

**[31] Joseph J. Thomson**

Birth: December 18, 1856, Cheetham Hill, Manchester, Lancashire, England, United Kingdom

Death: August 30, 1940, Cambridge, Cambridgeshire, England, UK

Known for: the Discovery of the Electron



Thomson in 1915

*"His work was so great that it cannot be compassed in a few words. His death is one of the greatest losses ever to occur to British science.*

*{Describing Ernest Rutherford upon his death at age 66. Thomson, then 80 years old, was once his teacher.}"*

*— Joseph John Thomson*

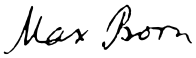
**[32] Max Born**

Birth: December 11, 1882, Breslau, German Empire

Death: January 5, 1970, Göttingen, West Germany

Known for: Quantum Mechanics





*"The belief that there is only one truth and that oneself is in possession of it seems to me the root of all the evil that is in the world"*

*— Max Born*

**[33] Francis Harry Compton Crick**

Birth: June 8, 1916, Northampton, Northamptonshire, England

Death: July 28, 2004, San Diego, Calif., U.S.

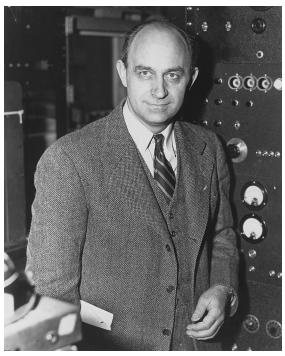
Known for: Molecular Biology



Max and Hedi Born in Indian clothes, Bangalore, India, c. 1937

*"Biologists must constantly keep in mind that what they see was not designed, but rather evolved."*

*— Francis Crick*



**Fermi in 1943**

**[34] Enrico Fermi**

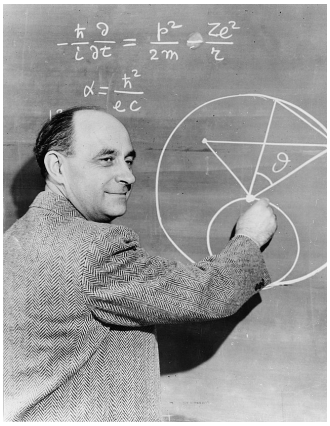
Birth: Sept. 29, 1901, Rome, Italy

Death: Nov. 28, 1954, Chicago, Ill., U.S.

Known for: Statistical mechanics

*"Whatever Nature has in store for mankind, unpleasant as it may be, men must accept, for ignorance is never better than knowledge."*

*— Enrico Fermi*



**Fermi at the blackboard with several formulae and a diagram of circles and triangles.**

**[35] Leonard Euler**

Birth: April 15, 1707, Basel, Switzerland

Death: September 18, 1783, Saint Petersburg, Russian Empire

Known for: Eighteenth-Century Mathematics

*"Logic is the foundation of the certainty of all the knowledge we acquire."*

*— Leonhard Euler*



**The young Liebig**

**[36] Justus Liebig**

Birth: May 12, 1803, Darmstadt, Grand Duchy of Hesse

Death: April 18, 1873, Munich, German Empire

Known for: Nineteenth-Century Chemistry




German stamp picturing Justus von Liebig, 1953

*"From one sublime genius—NEWTON—more light has proceeded than the labour of a thousand years preceding had been able to produce."*

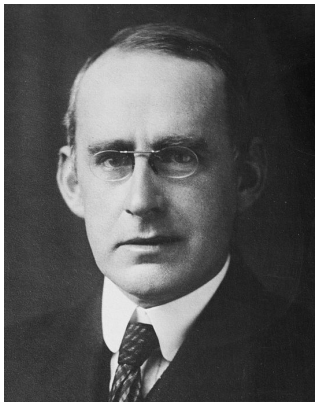
*— Justus Liebig*

**[37] Arthur Stanley Eddington**

Birth: December 28, 1882, Kendal, Westmorland, England

Death: November 22, 1944, Cambridge, Cambridgeshire, England

Known for: Modern astronomy



Sir Arthur Stanley Eddington

*"An ocean traveler has even more vividly the impression that the ocean is made of waves than that it is made of water."*

*— Arthur S. Eddington*

**[38] William Harvey**

Birth: April 1, 1578, Folkestone, Kent, England

Death: June 3, 1657, London

Known for: Circulation of the Blood





*"Doctrine once sown strikes deep its root, and respect for antiquity influences all men."*

— *William Harvey*




William Harvey on a 1957 Soviet postage stamp

**[39] Marcello Malpighi**

Birth: 1628

Death: 1694

Known for: Microscopic Anatomy

*"For Nature is accustomed to rehearse with certain large, perhaps baser, and all classes of wild (animals), and to place in the imperfect the rudiments of the perfect animals."*

— *Marcello Malpighi*



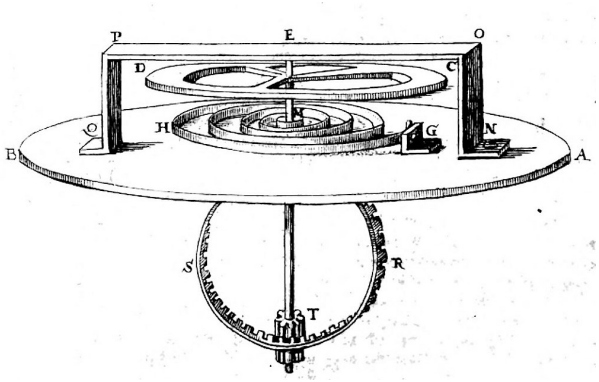
Christiaan Huygens

**[40] Christiaan Huygens**

Birth: 1629

Death: 1695

Known for: the Wave Theory of Light




Drawing of a balance spring invented by Huygens.

*"The world is my country, science is my religion."*

— *Christiaan Huygens*

**[41] Johann Carl Friedrich Gauss**

Birth: April 30, 1777, Brunswick, Duchy of Brunswick-Wolfenbüttel, Holy Roman Empire

Death: February 23, 1855, Göttingen, Kingdom of Hanover

Known for: Number theory, algebra, statistics, analysis, differential geometry, geodesy, geophysics, mechanics, electrostatics, astronomy, matrix theory and optics



Gauss on his deathbed (1855)

*"Astronomy and Pure Mathematics are the magnetic poles toward which the compass of my mind ever turns."*

*— Carl Friedrich Gauss*

**[42] Albrecht von Haller**

Birth: October 16, 1708, Bern, Swiss Confederacy

Death: December 12, 1777, Bern, Swiss Confederacy

Known for: Eighteenth-Century Medicine



Albrecht von Haller 1736

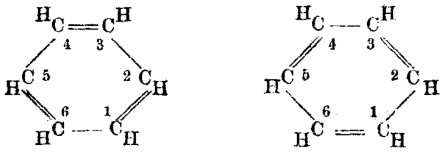
*"Nature never jests."*

*— Albrecht von Haller*

**[43] Friedrich August Kekule von Stradonitz**

Birth: September 7, 1829, Darmstadt, Grand Duchy of Hesse

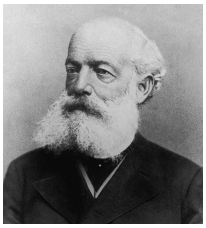
Death: July 13, 1896, Bonn, German Empire



Kekulé structure of benzene with alternating double bonds

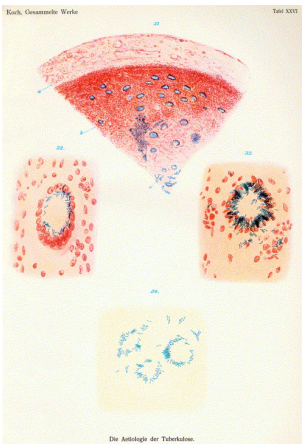
Known for: Theory of chemical structure, tetravalence of carbon, structure of benzene

*"Let us learn to dream, gentlemen, then perhaps we shall find the truth."*



August Kekulé

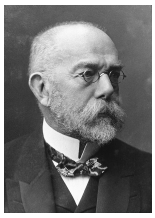
— *August Kekule*



**[44] Robert Koch**

Birth: Dec. 11, 1843, Clausthal, Hannover [now Clausthal-Zellerfeld, Germany]

Death: May 27, 1910, Baden-Baden, Germany



Known for: Bacteriology

**Koch's drawing of tuberculosis bacilli in 1882**

*"The day will come when man will have to fight noise as inexorably as cholera and the plague."*

— *Robert Koch*

**[45] Murray Gell-Mann**

Birth: September 15, 1929, Manhattan, New York City, United States

Known for: Gell-Mann and Low theorem, Elementary particles, quarks, Gell-Mann matrices

*"Think how hard physics would be if particles could think."*

— *Murray Gell-Mann*



**[46] Hermann Emil Louis Fischer**

Birth: October 09, 1852, Euskirchen, Rhine Province

Death: July 15, 1919, Berlin, Germany

Known for: Organic Chemistry

**Murray Gell-Mann**

*"To use a picture, I will say that enzyme and glucoside must join one another as lock and key, in order to be able to exert a chemical effect."*

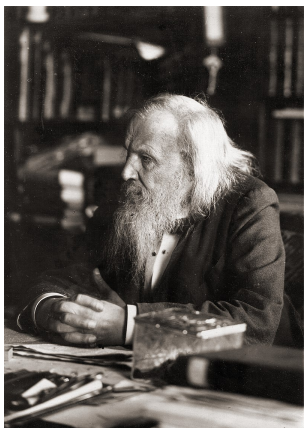
*— Hermann Emil Fischer*

**[47] Dmitri Mendeleev**

Birth: Jan. 27 [Feb. 8, New Style], 1834, Tobolsk, Siberia, Russian Empire

Death: Jan. 20 [Feb. 2], 1907, St. Petersburg, Russia

Known for: the Periodic Table of Elements



Mendeleev in 1897

*"Work, look for peace and calm in work; you will find it nowhere else."*

*— Dmitri Mendeleev*

**[48] Sheldon Glashow**

Birth: December 5, 1932, New York City, New York, USA

Known for: Electroweak theory & Georgi–Glashow model



Mendeleev, Alfred Werner, Adolf von Baeyer, and other prominent chemists

*"Some astrophysicists have convinced themselves that the fifth significant figure of the fine structure constant has changed over the past ten billion years."*

*— Sheldon L. Glashow*

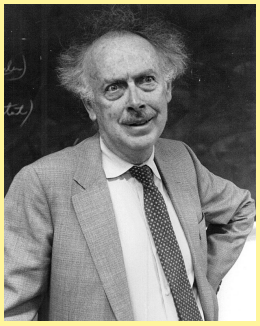
**[49] James Dewey Watson**

Birth: April 6, 1928, Chicago, Illinois, U.S

Known for: the Structure of DNA

*"Today, the theory of evolution is an accepted fact for everyone but a fundamentalist minority, whose objections are based not on reasoning but on doctrinaire adherence to religious principles."*

*— James D. Watson*



## ✓ Letter from James Watson to Max Delbrück. March 12, 1953

March 12, 1953

Dear Max

Thank you very much for your recent letters. We were quite interested in your account of the Pauling Seminar. The day following the arrival of your letter, I received a note from Pauling, mentioning that their model had been revised, and indicating interest in our model. We shall thus have to write him in the near future as to what we are doing. Until now we preferred not to write him since we did not want to commit ourselves until we were completely sure that all of the Van der Waals contacts were correct and that all aspects of our structure were stereochemically feasible. I believe now that we have made sure that our structure can be built and today we are laboriously calculating out exact atomic coordinates.

Our model (a joint project of Francis Crick and myself) bears no relationship to either the original or the revised Pauling-Corey-Schomaker models. It is a strange model and embodies several unusual features. However since DNA is an unusual substance, we are not hesitant in being bold. The main features of the model are (1) The basic structure is helical - it consists of two intertwining helices - the core of the helix is occupied by the purine and pyrimidine bases - the phosphates groups are on the outside. (2) The helices are not identical but complementary so that if one helix contains a purine base, the other helix contains a pyrimidine - this feature is a result of our attempt to make the residues equivalent and at the same time put the purines and pyrimidine bases in the center. The pairing of the purine with pyramidines is very exact and dictated by their desire to form hydrogen bonds - Adenine will pair

with Thymine while Guanine will always pair with Cytosine. For example [diagrams of base pairing] Thymine with Adenine, Cytosine with Guanine.

While my diagram is crude, in fact these pairs form 2 very nice hydrogen bonds in which all of the angles are exactly right. This pairing is based on the effective existence of only one out of the two possible tautomeric forms - in all cases we prefer the keto form over the enol[,] the amino over the imino. This is definitely an assumption but Jerry Donohue and Bill Cochran tell us that for all organic molecules so far examined, the keto and amino forms are present in preference to the enol and imino possibilities.

The model has been derived almost entirely from stereochemical considerations with the only x-ray consideration being the spacing between the pair of bases 3.4 A which was originally found by Astbury. It tends to build itself with approximately 10 residues per tern in 34 A. The screw is right handed.

The x-ray pattern approximately agreed with the model, but since the photographs available to us are poor and meagre (we have no prototypes of our own and like Pauling must use Astbury's photographs) this agreement in no way constitutes a proof of our model. We are certainly a long way from proving its correctness. To do this we must obtain collaboration from the group at Kings College London who possess very excellent photographs of a crystalline phase in addition to rather good photographs of a paracrystalline phase. Our model has been made in reference to the paracrystalline form, and as yet we have no clear idea as to how these helices pack together to form the crystalline phase.

In the next day or so Crick and I shall send a note to Nature proposing our structure as a possible model, at the same time emphasizing its provisional nature and the lack of proof in its favor. Even if wrong I believe it to be interesting since it promises a concrete example of a structure composed of complementary chains. If by chance, it is right then I suspect we may be making a slight dent into the manner in which DNA can reproduce itself. For these reasons (in addition to many others) I prefer this type of model over Pauling's which if true would tell us next to nothing about [the] manner of DNA reproduction.

I shall write you in a day or so about the recombination paper. Yesterday I received a very interesting note from Bill Hayes. I believe he is sending you a copy.

I have met Alfred Tissieus recently. He seems very nice. He speaks fondly of Pasadena and I suspect has not yet become accustomed to being a Fellow of Kings.

My regards to Mary

Jim

*P.S. We would prefer your not mentioning this letter to Pauling. When our letter to Nature is completed we shall send him a copy. We should like to send him coordinates.*





Bardeen in 1956



John Bardeen, William Shockley and Walter Brattain at Bell Labs, 1948

## [50] John Bardeen

Birth: May 23, 1908, Madison, Wisconsin, U.S

Death: Jan. 30, 1991, Boston, Massachusetts, U.S

Known for: Superconductivity and BCS theory

*"Science is a field which grows continuously with ever expanding frontiers. Further, it is truly international in scope. Any particular advance has been preceded by the contributions of those from many lands who have set firm foundations for further developments. The Nobel awards should be regarded as giving recognition to this general scientific progress as well as to the individuals involved.*

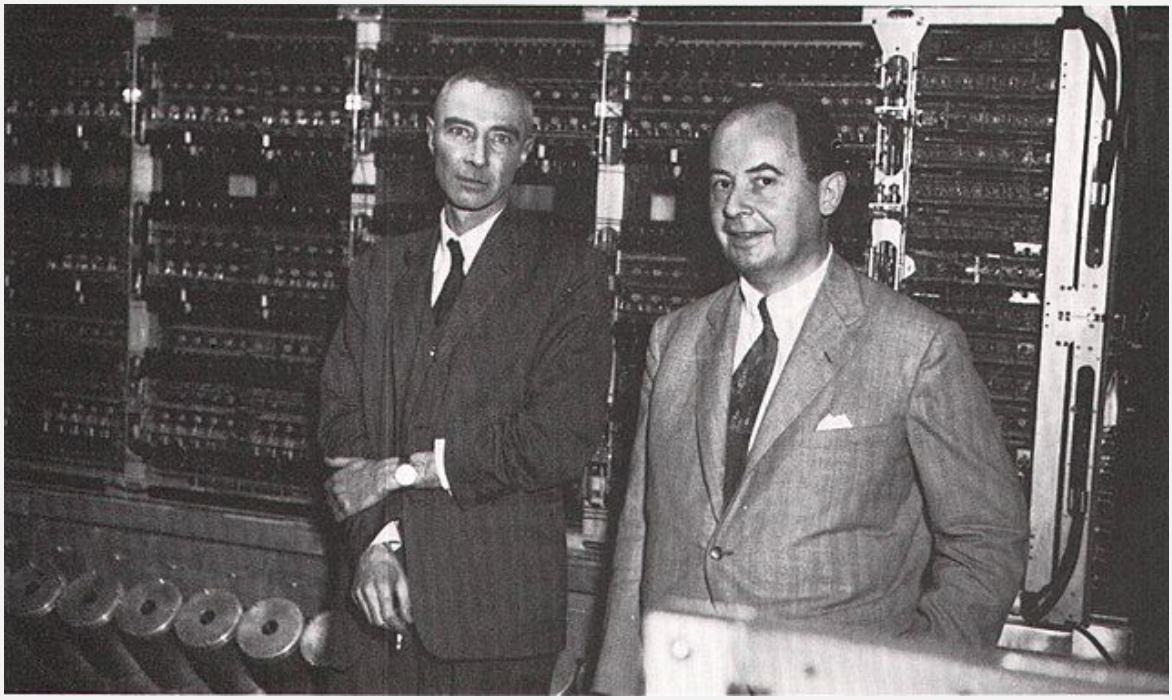
*Further, science is a collaborative effort. The combined results of several people working together is often much more effective than could be that of an individual scientist working alone."*

*— John Bardeen*

## [51] John von Neumann



**John von Neumann as child**



**John von Neumann (left) and Institute for Advanced Study (IAS) Director J. Robert Oppenheimer in front of the IAS Computer in Princeton, New Jersey.**

Birth: December 28, 1903, Budapest, Austria-Hungary

Death: February 8, 1957, Walter Reed General Hospital Washington, D.C.

Known for: the Modern Computer



Neumann in the 1940s

*"Young man, in mathematics you don't understand things. You just get used to them."*

*— John von Neumann*

**[52] Richard P. Feynman**

Birth: May 11, 1918, New York, N.Y., U.S.

Death: Feb. 15, 1988, Los Angeles, California

Known for: Quantum Electrodynamics



Richard P. Feynman

*"Study hard what interests you the most in the most undisciplined, irreverent and original manner possible."*

*— Richard Feynman*

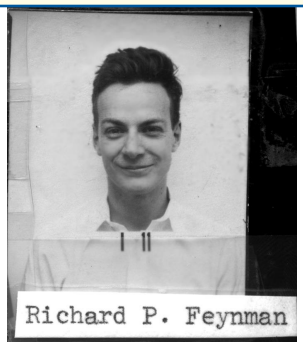
**Richard Feynman's letter to one of his former student.**

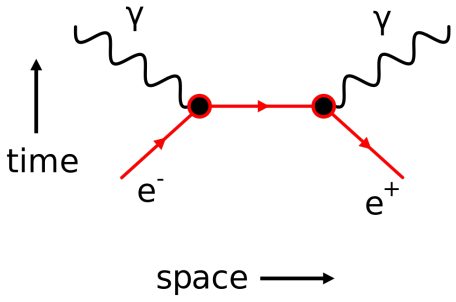
27 October 1964

Mr. David Eisenman

Harvard University

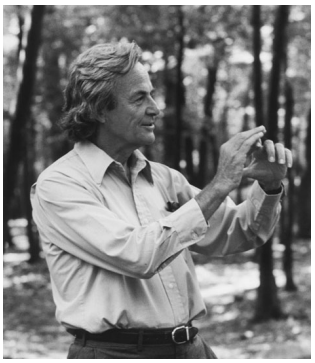
Adams C-56




Feynman diagram of electron/positron annihilation

Cambridge 38, Massachusetts



Richard Feynman at the Robert Treat Paine Estate in Waltham, Massachusetts, in 1984

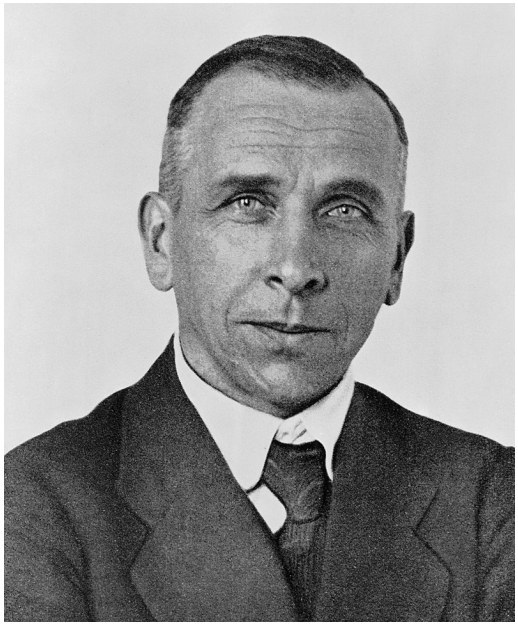
Dear Mr. Eisenman:

Thank you for your interesting letter describing that wonderful phenomenon. I guess your "zero" is displaced outward but the inner nerve connections are as usual, so you have to "converge" to see parallel. Half way through your letter, I though, "poor guy", but on reading of the manifold advantages that your singular ability has for your [sic], I am going back to the bathroom mirror and practice harder this time, again and again, to see if I can do it too. Evidently you are a genetically advantageous mutation, and we can guess now where the evolution of the human race is headed.

Sincerely,

Richard P. Feynman

Richard P. Feynman



**[53] Alfred Lothar Wegener**

Birth: Nov. 1, 1880, Berlin, Germany

Death: Nov. 1930, Greenland

Known for: Continental Drift

Alfred Wegener

*"Scientists still do not appear to understand sufficiently that all earth sciences must contribute evidence toward unveiling the state of our planet in earlier times, and that the truth of the matter can only be reached by combing all this evidence. ... It is only by combing the information furnished by all the earth sciences that we can hope to determine 'truth' here, that is to say, to find the picture that sets out all the known facts in the best arrangement and that therefore has*

*the highest degree of probability. Further, we have to be prepared always for the possibility that each new discovery, no matter what science furnishes it, may modify the conclusions we draw."*

*— Alfred Wegener*



**[54] Stephen W. Hawking**

Birth: Jan. 8, 1942, Oxford, Oxfordshire, England

Known for: Quantum Cosmology

*"Intelligence is the ability to adapt to change."*

*— Stephen Hawking*

✔ **Stephen Hawking was born on the 300th death anniversary of Galileo Galilei, and died on the 139th birth anniversary of Albert Einstein.**

- **Memories of my father - Lucy Hawking**

On the bleak greyness of a Cambridge spring day, we set off in a cortège of black cars towards Great St Mary's Church, the university church where distinguished academics by tradition have their funeral services. Out of term, the streets seemed muted. Cambridge looked empty, not even a wandering tourist in sight. The only spikes of colour came from the blue flashing lights of the police motorcycle outriders, guarding the hearse with my father's coffin in it, stopping the sparse traffic as we went.

And then we turned left. And saw the crowds, massed along one of the most recognisable streets in the world, King's Parade, the heart of Cambridge itself. I have never seen so many people so silent. With banners, flags, cameras and mobile phones held aloft, the huge numbers of people lining the streets stood in quiet respect as the head porter of Gonville and Caius, my father's Cambridge college, dressed ceremonially in his bowler hat and carrying an ebony cane, walked solemnly along the street to meet the hearse and walk it to the church.

My aunt squeezed my hand as we both burst into tears. "He would have loved this," she whispered to me. Since my father died, there has been so much he would have loved, so much I wish he could have known. I wish he could have seen the extraordinary outpouring of affection towards him, coming from all around the world. I wish he could have known how dearly loved and respected he was by millions of people he had never met. I wish he had known he would be interred in Westminster Abbey, between two of his scientific heroes, Isaac Newton and Charles Darwin, and that as he was laid to rest in the earth his voice would be beamed by a radio telescope towards a black hole.

But he would also have wondered what all the fuss was about. He was a surprisingly modest man who, while adoring the limelight, seemed baffled by his own fame. One phrase in this book jumped off the page at me as summing up his attitude to himself: "if I have made a contribution." He is the only person who would have added the "if" to that sentence. I think everyone else felt pretty sure he had. And what a contribution it is. Both in the overarching grandeur of his work in cosmology, exploring the structure and origins of the universe itself and in his completely human bravery and humour in the face of his challenges. He found a way to reach beyond the limits of knowledge while surpassing the limits of endurance at the same time. I believe it was this combination which made him so iconic yet also so reachable, so accessible. He suffered but he persevered. It was effortful for him to communicate—but he made that effort, constantly adapting his equipment as he further lost mobility. He selected his words precisely so that they would have maximum impact when spoken in that flat electronic voice which became so oddly expressive when used by him. When he spoke, people listened, whether it was his views on the NHS or on the expansion of the universe, never losing an opportunity to include a joke, delivered in the most deadpan fashion but with a knowing twinkle in his eyes.

My father was also a family man, a fact lost on most people until the film The Theory of Everything came out in 2014. It certainly was not usual, in the 1970s, to find a disabled person who had a spouse and children of his own nor one with such a strong sense of autonomy and independence. As a small child, I intensely disliked the way strangers felt free to stare at us, sometimes with open mouths, as my father piloted his wheelchair at insane speeds through Cambridge, accompanied by two mop-haired blond children, often running alongside while trying to eat an ice cream. I thought it was incredibly rude. I used to try to stare back but I don't think my indignation ever hit the target, especially not from a childish face smeared with melted lolly.

It wasn't, by any stretch of the imagination, a normal childhood. I knew that—and yet at the same time I didn’t. I thought it was perfectly normal to ask grown-ups lots of challenging questions because this is what we did at home. It was only when I allegedly reduced a vicar to tears with my close examination of his proof of the existence of God

that it started to dawn on me that this was unexpected. As a child, I didn't think of myself as the questioning type — I believed that was my elder brother, who in the manner of elder brothers outsmarted me at every turn (and indeed still does). I remember one family holiday—which, like so many family holidays, mysteriously coincided with an overseas physics conference. My brother and I attended some of the lectures — presumably to give my mother a break from her wraparound caring duties. In those days, physics lectures were not popular and definitely not for kids. I sat there, doodling on my notepad, but my brother put his skinny littleboy arm in the air and asked a question of the distinguished academic presenter while my father glowed with pride. I am often asked, "What is it like to be Stephen Hawking's daughter?" and inevitably, there is no brief answer that fits the bill. I can say that the highs were very high, the lows were profound and that in between existed a place which we used to call "normal — for us," an acceptance as adults that what we found normal wouldn't count as such for anyone else. As time dulls the raw grief, I have reflected that it could take me forever to process our experiences. In a way, I'm not even sure I want to. Sometimes, I just want to hold on to the last words my father said to me, that I had been a lovely daughter and that I should be unafraid. I will never be as brave as him — I'm not by nature a particularly courageous person — but he showed me that I could try. And that trying might turn out to be the most important part of courage.

My father never gave up, he never shied away from the fight. At the age of seventy-five, completely paralysed and able to move only a few facial muscles, he still got up every day, put on a suit and went to work. He had stuff to do and was not going to let a few trivialities get in his way. But I have to say, had he known about the police motorcycle outriders who were present at his funeral, he would have requested them each day to navigate him through the morning traffic from his home in Cambridge to his office.

Happily, he did know about this book. It was one of the projects he worked on in what would turn out to be his last year on Earth. His idea was to bring his contemporary writings together into one volume. Like so many things that have happened since he died, I wish he could have seen the final version. I think he would have been very proud of this book and even he might have had to admit, in the end, that he had made a contribution after all.

Lucy Hawking

July 2018




Hawking taking a zero-gravity flight in a reduced-gravity aircraft, April 2007

## [55] Antonie van Leeuwenhoek

Birth: Oct. 24, 1632, Delft, Neth.

Death: Aug. 26, 1723, Delft

Known for: the Simple Microscope






*"My determination is not to remain stubbornly with my ideas but I'll leave them and go over to others as soon as I am shown plausible reason which I can grasp. This is the more true since I have no other purpose than to place truth before my eyes so far as it is in my power to embrace it; and to use the little talent I have received to draw the world away from its old heathenish superstitions and to go over to the truth and to stick to it."*

*— Antony Van Leeuwenhoek*

**[56] Max von Laue**

Birth: Oct. 09, 1879, Pfaffendorf, Kingdom of Prussia, German Empire

Death: April 24, 1960, West Berlin

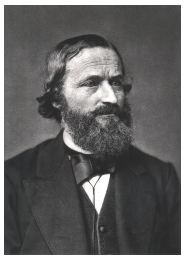
Known for: X-ray Crystallography



Laue in 1929

*"For in 1900 all electromagnetic radiation of longer wavelengths was already known at least to the extent that one could not seek in it the more striking characteristics of X-rays such as, for example, the strong penetrating power."*

*—Max von Laue*

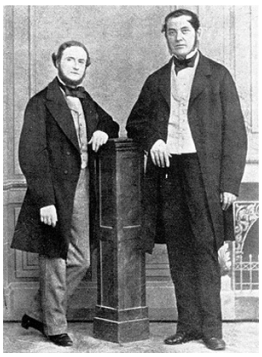


Gustav Robert Kirchhoff

**[57] Gustav Kirchhoff**

Birth: March 12, 1824, Königsberg, Kingdom of Prussia [present-day Russia]

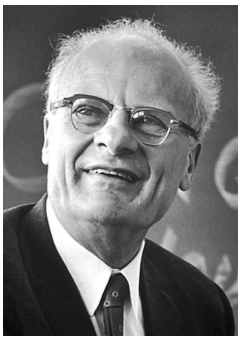
Death: October 17, 1887, Berlin, Prussia, German Empire [present-day Germany]



Kirchhoff (left) and Robert Bunsen, c. 1850

Known for: Kirchhoff's circuit laws, Kirchhoff's laws of spectroscopy, Kirchhoff's law of thermochemistry and Kirchhoff's law of thermal radiation

> *"Look here, I have succeeded at last in fetching some gold from the sun.*
>
> *{After his banker questioned the value of investigating gold in the Fraunhofer lines of the sun and Kirchhoff handing him over a medal he was awarded for his investigations.}"*
>
> *— Gustav Kirchhoff*



Hans Albrecht Bethe

**[58] Hans Bethe**

Birth: July 2, 1906, Strassburg, Ger. [now Strasbourg, France]

Death: March 6, 2005, Ithaca, N.Y., U.S.

Known for: the Energy of the Sun

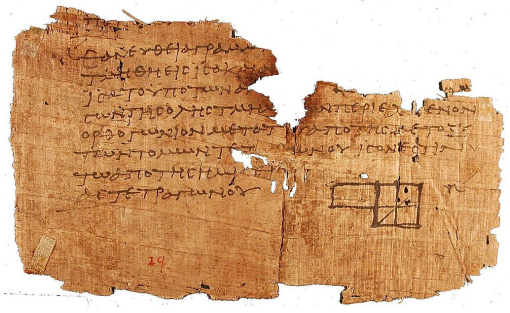
> *"We need science education to produce scientists, but we need it equally to create literacy in the public. Man has a fundamental urge to comprehend the world about him, and science gives today the only world picture which we can consider as valid. It gives an understanding of the inside of the atom and of the whole universe, or the peculiar properties of the chemical substances and of the manner in which genes duplicate in biology. An educated layman can, of course, not contribute to science, but can enjoy and participate in many scientific discoveries which as constantly made. Such participation was quite common in the 19th century, but has unhappily declined. Literacy in science will enrich a person's life."*
>
> *— Hans A. Bethe*



**[59] Euclid**

Known for: the Foundations of Mathematics





A papyrus fragment of Euclid's Elements dated to c. 75–125 AD.

*"The laws of nature are but the mathematical thoughts of God."*

*— Euclid*



Gregor Johann Mendel

**[60] Gregor Mendel**

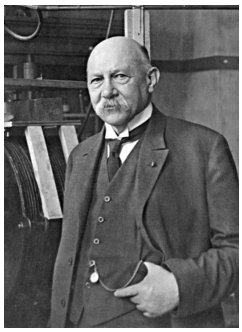
Birth: July 22, 1822, Heinzendorf, Austria [now Hynčice, Czech Rep.]

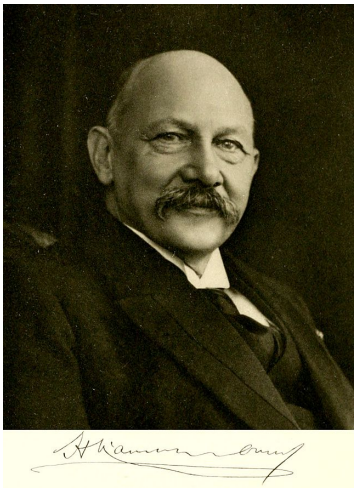
Death: Jan. 6, 1884, Brünn, Austria-Hungary [now Brno, Czech Rep.]

Known for: the Laws of Inheritance

*"I am convinced that it will not be long before the whole world acknowledges the results of my work."*

*— Gregor Mendel*





**[61] Heike Kamerlingh Onnes**

Birth: September 21, 1853, Groningen, Netherlands

Death: February 21, 1926, Leiden, Netherlands

Known for: Superconductivity, Onnes-effect and Virial Equation of State

*"The experiment left no doubt that, as far as accuracy of measurement went, the resistance disappeared. At the same time, however, something unexpected occurred. The disappearance did not take place gradually but abruptly. From 1/500 the resistance at 4.2K, it could be established that the resistance had become less than a thousand-millionth part of that at normal*

*temperature. Thus the mercury at 4.2K has entered a new state, which, owing to its particular electrical properties, can be called the state of superconductivity."*

*— Heike Kamerlingh Onnes*

**[62] Thomas Hunt Morgan**

Birth: September 25, 1866, Lexington, Kentucky

Death: December 04, 1945, Pasadena, California

Known for: the Chromosomal Theory of Heredity



1931 drawing of Thomas Hunt Morgan

*"Except for the rare cases of plastid inheritance, the inheritance of all known cofactors can be sufficiently accounted for by the presence of genes in the chromosomes. In a word the cytoplasm may be ignored genetically."*

*— Thomas Hunt Morgan*

**[63] Hermann von Helmholtz**

Birth: August 31, 1821, Potsdam, Kingdom of Prussia

Death: September 08, 1894, Charlottenburg, German Empire

Known for: the Rise of German Science



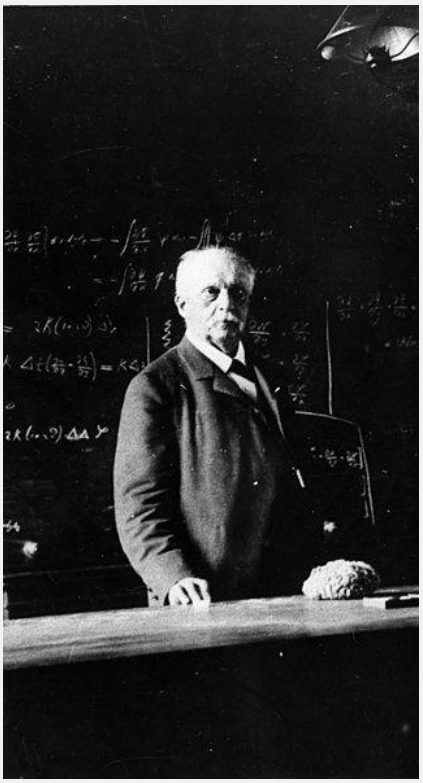
Helmholtz in 1848

*"What the recent physiology of the senses has shown by the way of experience is what Kant had tried to show for the representations of the human mind in general when he laid out the participation of the particular, built-in rules of the mind, the organization of the mind as it were, in our representations."*

*— Hermann von Helmholtz*

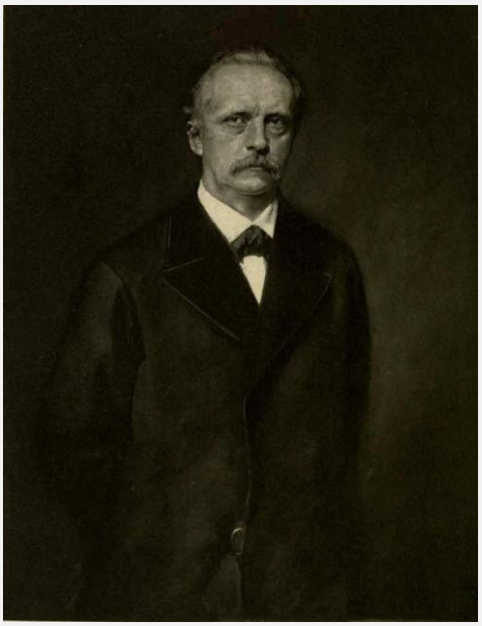



Helmholtz's statue in front of Humboldt University in Berlin





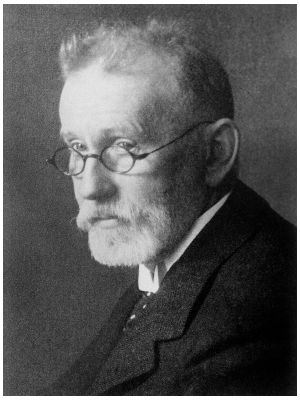
von Helmholtz's last picture, taken three days before his final illness



Helmholtz in 1876

**Hermann von Helmholtz** was a German physician, physicist, and philosopher who made significant contributions to several scientific fields during the 19th century. He is widely regarded as one of the most important scientists of his time. Born in 1821 in Potsdam, Prussia, **Helmholtz** initially studied medicine before turning to physics and mathematics. He is best known for his work on the **conservation of energy**, the **law of thermodynamics**, and the **study of electromagnetism**. Helmholtz also developed the theory of color vision, which is still taught in universities today. Among his many accomplishments, **Helmholtz** developed the **ophthalmoscope**, an instrument used to examine the interior of the eye, and he conducted groundbreaking research on the physiology of the nervous system. He also made significant contributions to the **study of acoustics**, including the development of a mathematical model of the human ear and the invention of the **Helmholtz resonator**, a device used to measure the frequency of sound waves. In addition to his scientific work, **Helmholtz** was a prolific writer and thinker who contributed to the field of philosophy, particularly in the areas of epistemology and metaphysics. He was a strong advocate for the use of empirical methods in scientific research, and his work helped to bridge the gap between the natural sciences and the humanities. **Hermann von Helmholtz** died in 1894 at the age of 73. His work and legacy continue to influence and inspire scientists and philosophers around the world.

**[64] Paul Ehrlich**





Birth: March 14, 1854, Strehlen, Lower Silesia, German Kingdom of Prussia

Death: August 20, 1915, Bad Homburg, Hesse, Germany

Known for: Chemotherapy

> *"Few problems are less recognized, but more important than, the accelerating disappearance of the earth's biological resources. In pushing other species to extinction, humanity is busy sawing off the limb on which it is perched."*
>
> *— Paul Ehrlich*

**[65] Ernst Walter Mayr**



Paul Ehrlich around 1900 in his Frankfurt office

Birth: July 05, 1904, Kempten, Germany

Death: February 03, 2005, Bedford, Massachusetts, United States

Known for: Evolutionary Theory

> *"According to the concept of transformational evolution, first clearly articulated by Lamarck, evolution consists of the gradual transformation of organisms from one condition of existence to another."*
>
> *— Ernst Mayr*

**[66] Theodosius Grygorovych Dobzhansky**

Birth: January 25, 1900, Nemyriv, Russian Empire

Death: December 18, 1975, San Jacinto, California, United States

Known for: the Modern Synthesis

> *"Nothing in biology makes sense except in the light of evolution."*
>
> — *Theodosius Dobzhansky*



Delbrück in the early 1940s

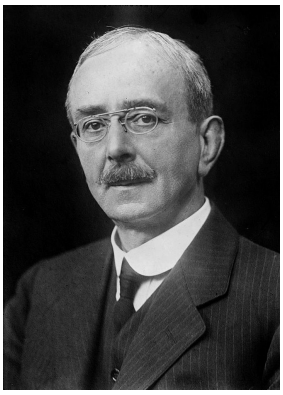
**[67] Max Delbruck**

Birth: September 04, 1906, Berlin, German Empire

Death: March 9, 1981, Pasadena, California, United States

Known for: the Bacteriophage

> *"The scientist has in common with the artist only this: that he can find no better retreat from the world than his work and no stronger link with the world than his work."*
>
> — *Max Delbruck*



Sir Charles Scott Sherrington

**[68] Charles Scott Sherrington**

Birth: November 27, 1857, Islington, Middlesex, England

Death: March 04, 1952, Eastbourne, Sussex, England

Known for: Neurophysiology

> *"Swiftly the brain becomes an enchanted loom, where millions of flashing shuttles weave a dissolving pattern-always a meaningful pattern-though never an abiding one."*

*— Charles Sherrington*

**[69] Jean Baptiste Lamarck**

Birth: August 01, 1744, Bazentin, Picardy, France

Death: December 18, 1829, Paris, France

Known for: the Foundations of Biology



Jean-Baptiste Lamarck

*"It is not enough to discover and prove a useful truth previously unknown, but that it is necessary also to be able to propagate it and get it recognized."*

*— Jean-Baptiste Lamarck*

**[70] William Bayliss**

Birth: May 2, 1860, Wednesbury, Staffordshire, England

Death: August 27, 1924, London, England

Known for: Modern Physiology



Lamarck, late in life

*"But at the same time, there must never be the least hesitation in giving up a position the moment it is shown to be untenable. It is not going too far to say that the greatness of a scientific investigator does not rest on the fact of his having never made a mistake, but rather on his readiness to admit that he has done so, whenever the contrary evidence is cogent enough."*

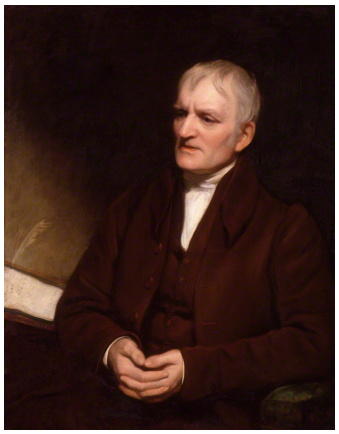
*— William Bayliss*

**[71] John Dalton**

Birth: Sept. 5 or 6, 1766, Eaglesfield, Cumberland, England

Death: July 27, 1844, Manchester

Known for: the Theory of the Atom



*It's the right idea, but not the right time.*



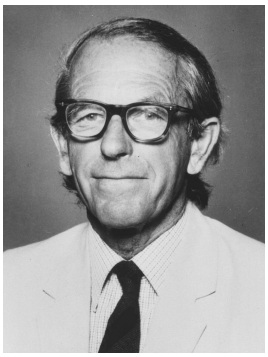
*— John Dalton*

**[72] Frederick Sanger**

Birth: August 13, 1918, Rendcomb, Gloucestershire, England

Death: November 19, 2013, Cambridge, Cambridgeshire, England

Known for: the Genetic Code



Frederick Sanger

*"A DNA sequence for the genome of bacteriophage ΦX174 of approximately 5,375 nucleotides has been determined using the rapid and simple 'plus and minus' method. The sequence identifies many of the features responsible for the production of the proteins of the nine known genes of the organism, including initiation and termination sites for the proteins and RNAs. Two pairs of genes are coded by the same region of DNA using different reading frames."*

*— Frederick Sanger*

**[73] Louis Victor de Broglie**

Birth: August 15, 1892, Dieppe, France

Death: March 19, 1987, Louveciennes, France

Known for: Wave/Particle Duality



Broglie in 1929

*"After long reflection in solitude and meditation, I suddenly had the idea, during the year 1923, that the discovery made by Einstein in 1905 should be generalised by extending it to all material particles and notably to electrons."*

*— Louis de Broglie*

**[74] Carl Linnaeus**

Birth: May 23, 1707, Råshult, Stenbrohult parish (now within Älmhult Municipality), Sweden

Death: January 10, 1778, Hammarby (estate), Danmark parish (outside Uppsala), Sweden

Known for: the Binomial Nomenclature

*"When all the thoughts are concerning one thing and the person loses interest in other things, the melancholy begins."*

*— Carl Linnaeus*



Carl Linnaeus in Laponian costume (1737)

**[75] J. Robert Oppenheimer**

Birth: April 22, 1904, New York, N.Y., U.S.

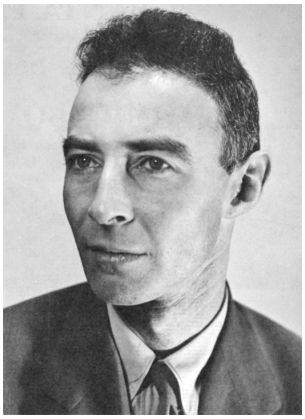
Death: Feb. 18, 1967, Princeton, N.J.

Known for: the Atomic Era

*"The optimist thinks this is the best of all possible worlds. The pessimist fears it is true."*

*— J. Robert Oppenheimer*

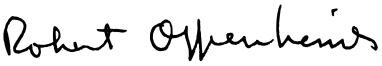
**[76] Sir Alexander Fleming**



Birth: Aug. 6, 1881, Lochfield Farm, Darvel, Ayrshire, Scotland

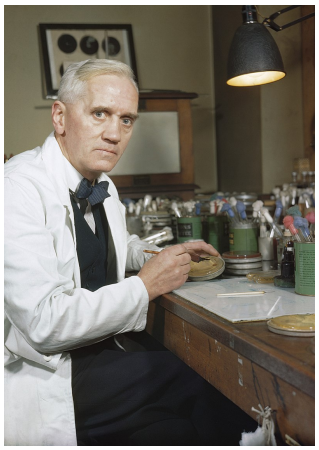
Death: March 11, 1955, London, England

Known for: Penicillin



> *"One sometimes finds what one is not looking for."*
>
> *— Alexander Fleming*

**[77] Jonas Edward Salk**



Birth: October 28, 1914, New York

Death: June 23, 1995, La Jolla, California, United States

Known for: Vaccination

**Fleming in his laboratory c. 1943**

> *"There is hope in dreams, imagination, and in the courage of those who wish to make those dreams a reality."*
>
> *— Jonas Salk*

**[78] Robert Boyle**




Birth: Jan. 25, 1627, Lismore Castle, County Waterford, Ireland

Death: Dec. 31, 1691, London, England

Known for: Boyle's law

**Faroe Islands postage stamp commemorating Fleming**

*"Those distinct substances, which concretes generally either afford, or are made up of, may, without very much inconvenience, be called the elements or principles of them."*

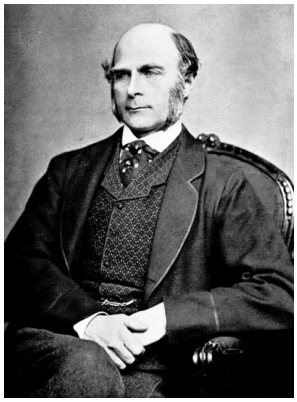
*— Robert Boyle*

**[79] Francis Galton**

Birth: Feb. 16, 1822, near Sparkbrook, Birmingham, Warwickshire, England

Death: Jan. 17, 1911, Grayshott House, Haslemere, Surrey

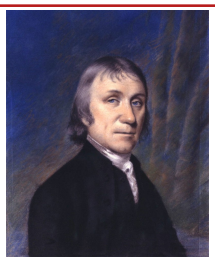
Known for: Eugenics



Galton in the 1850s

*"Men who leave their mark on the world are very often those who, being gifted and full of nervous power, are at the same time haunted and driven by a dominant idea, and are therefore within a measurable distance of insanity."*

*— Francis Galton*



Joseph Priestley

**[80] Joseph Priestley**

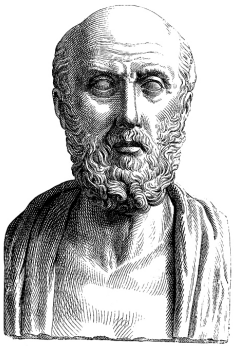
Birth: March 13, 1733, Birstall Fieldhead, near Leeds, Yorkshire [now West Yorkshire], England

Death: Feb. 6, 1804, Northumberland, Pa., U.S.

Known for: Discovery of oxygen

*"We should like to have some towering geniuses, to reveal us to ourselves in color and fire, but of course they would have to fit into the pattern of our society and be able to take orders from sound administrative types."*

— *Joseph Priestley*



**[81] Hippocrates**

Known for: Medicine

*"Let food be thy medicine and medicine be thy food."*

Hippocrates of Kos

— *Hippocrates*




**[82] Pythagoras**

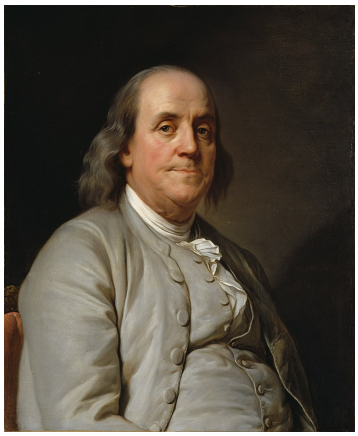
Known for: Pythagorean Theorem

*"Educate the children and it won't be necessary to punish the men."*

— *Pythagoras*

*"There is geometry in the humming of the strings. There is music in the spacing of the spheres."*

— *Pythagoras*



**[83] Benjamin Franklin**

Birth: January 17, 1706, Boston, Massachusetts Bay, British America

Death: April 17, 1790, Philadelphia, Pennsylvania, U.S.

Known for: Electricity



*"In wine there is wisdom, in beer there is Freedom, in water there is bacteria."*

*— Benjamin Franklin*



Benjamin Franklin Drawing Electricity from the Sky c. 1816

**[84] Leonardo da Vinci**

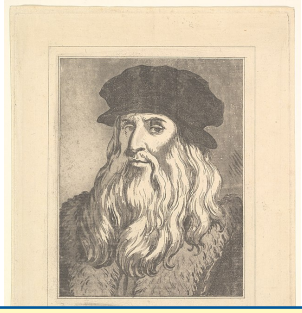
Birth: April 15, 1452, Anchiano, near Vinci, Republic of Florence [now in Italy]

Death: May 2, 1519, Cloux [now Clos-Luce], France

Known for: Mechanics and Cosmology

*"Painting is poetry that is seen rather than felt, and poetry is painting that is felt rather than seen."*

*— Leonardo da Vinci*



Leonardo da Vinci

### ✓ Leonardo da Vinci Letter to Ludovico Sforza, Duke of Milan

My Most Illustrious Lord,

Having now sufficiently seen and considered the achievements of all those who count themselves masters and artificers of instruments of war, and having noted that the invention and performance of the said instruments is in no way different from that in common usage, I shall endeavour, while intending no discredit to anyone else, to make myself understood to Your Excellency for the purpose of unfolding to you my secrets, and thereafter offering them at your complete disposal, and when the time is right bringing into effective operation all those things which are in part briefly listed below:

I have plans for very light, strong and easily portable bridges with which to pursue and, on some occasions, flee the enemy, and others, sturdy and indestructible either by fire or in battle, easy and convenient to lift and place in position. Also means of burning and destroying those of the enemy.

I know how, in the course of the siege of a terrain, to remove water from the moats and how to make an infinite number of bridges, mantlets and scaling ladders and other instruments necessary to such an enterprise.

Also, if one cannot, when besieging a terrain, proceed by bombardment either because of the height of the glacis or the strength of its situation and location, I have methods for destroying every fortress or other stranglehold unless it has been founded upon a rock or so forth.

I have also types of cannon, most convenient and easily portable, with which to hurl small stones almost like a hail-storm; and the smoke from the cannon will instil a great fear in the enemy on account of the grave damage and confusion.

Also, I have means of arriving at a designated spot through mines and secret winding passages constructed completely without noise, even if it should be necessary to pass underneath moats or any river.

Also, I will make covered vehicles, safe and unassailable, which will penetrate the enemy and their artillery, and there is no host of armed men so great that they would not break through it. And behind these the infantry will be able to follow, quite uninjured and unimpeded.

Also, should the need arise, I will make cannon, mortar and light ordnance of very beautiful and functional design that are quite out of the ordinary.

Where the use of cannon is impracticable, I will assemble catapults, mangonels, trebuckets and other instruments of wonderful efficiency not in general use. In short, as the variety of circumstances dictate, I will make an infinite number of items for attack and defence.

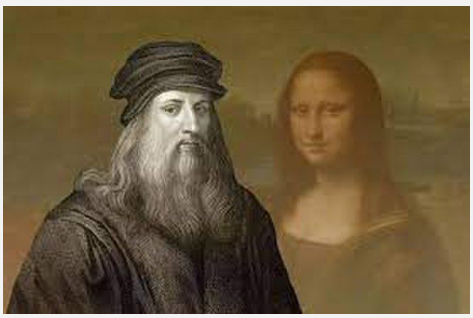
And should a sea battle be occasioned, I have examples of many instruments which are highly suitable either in attack or defence, and craft which will resist the fire of all the heaviest cannon and powder and smoke.

In time of peace I believe I can give as complete satisfaction as any other in the field of architecture, and the construction of both public and private buildings, and in conducting water from one place to another.

Also I can execute sculpture in marble, bronze and clay. Likewise in painting, I can do everything possible as well as any other, whosoever he may be.

Moreover, work could be undertaken on the bronze horse which will be to the immortal glory and eternal honour of the auspicious memory of His Lordship your father, and of the illustrious house of Sforza.

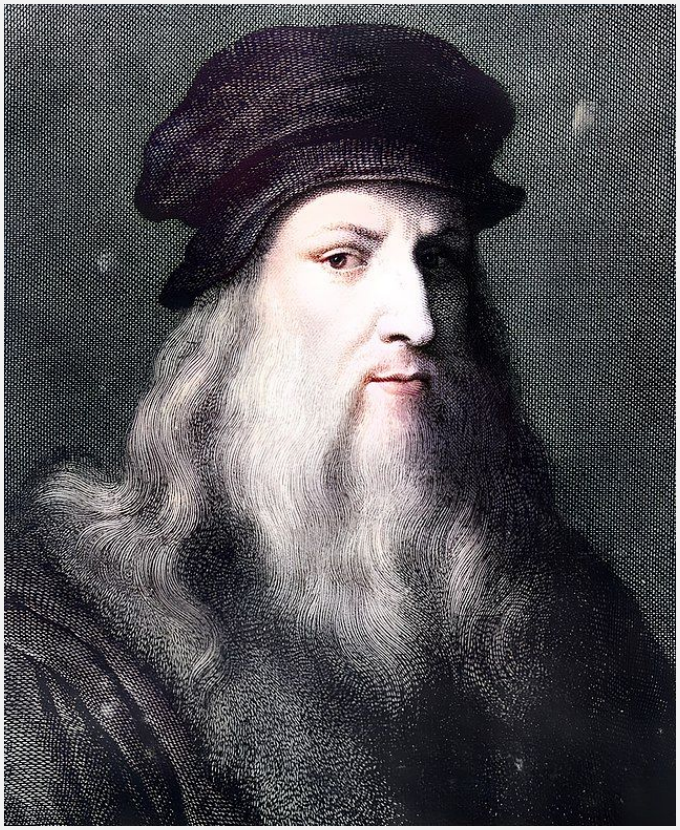
And if any of the above-mentioned things seem impossible or impracticable to anyone, I am most readily disposed to demonstrate them in your park or in whatsoever place shall please Your Excellency, to whom I commend myself with all possible humility.

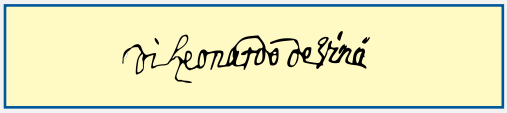


**The image of Leonardo Da Vinci and one of his most famous paintings 'Mona Lisa Smile'.**




**The Baptism of Christ (1472–1475) by Verrocchio and Leonardo, Uffizi Gallery**





**Leonardo da Vinci** (1452-1519) was one of the most influential and renowned figures of the **Renaissance period**. He was a true polymath, excelling in various fields such as painting, sculpture, architecture, and engineering. He was also deeply interested in science and made numerous important contributions in the field.

## ✓ Early Life and Education

Leonardo was born in the small town of Vinci, Italy, as the illegitimate son of a notary and a peasant woman. He grew up in his father's household and was given a good education. At a young age, Leonardo showed a talent for drawing and painting. He was apprenticed to **Andrea del Verrocchio**, a famous artist in Florence, where he honed his skills in painting, sculpture, and other artistic disciplines.

## ✓ Artistic Career

Leonardo's artistic career spanned several decades, and his paintings remain some of the most iconic and celebrated works of art in history. Among his most famous works are the **Mona Lisa**, **The Last Supper**, and **The Vitruvian Man**. His paintings were notable for their attention to detail and realism, and he was a master of chiaroscuro, a technique that uses light and shadow to create the illusion of depth and dimensionality. **Leonardo** was also a skilled sculptor and architect. He designed numerous buildings and structures, including churches, palaces, and military fortifications. His **architectural designs** were notable for their elegance and functionality, and many of his ideas were ahead of their time.

## ✓ Scientific Contributions

**Leonardo's interests** extended beyond the arts, and he made significant contributions to science and technology. One of his key areas of interest was anatomy, and he carried out detailed dissections of **human bodies** to better understand the **human form**. He produced a series of drawings and notes that provided a detailed understanding of the **human musculature** and bone structure, and these remain some of the most accurate depictions of human anatomy from the time. Leonardo was also interested in optics, and he developed a detailed understanding of light and the human eye. He produced some of the earliest detailed drawings of the eye, and his work on perspective helped to establish the rules that govern how objects are perceived in space. He also explored the properties of light and shadow, and his studies in this area helped to lay the groundwork for **modern optics**. In addition, Leonardo was interested in physics and mechanics, and he designed numerous machines and devices, including flying machines, weapons, and hydraulic systems. His work in this area helped to pave the way for the development of modern engineering and technology.

## ✓ Philosophical and Political Views

**Leonardo** was also a philosopher and thinker, and his ideas on art, science, and politics continue to be studied and debated today. He believed that art was a **reflection of nature** and that artists should strive to depict the world as accurately as possible. He also believed in the importance of observation and experimentation, and his scientific work was characterized by a rigorous attention to detail and a willingness to question established beliefs. **Leonardo's political views** were also noteworthy. He was a pacifist who believed in the importance of individual freedom

and human rights. He was critical of the church and the ruling classes, and his ideas on democracy and equality were ahead of their time.

## ✓ Legacy

**Leonardo da Vinci's contributions** to art, science, and philosophy were vast and far-reaching, and his legacy continues to be felt today. His work helped to define the **Renaissance period**, and his paintings remain some of the most iconic and celebrated works of art in history. His scientific and technological ideas helped to pave the way for **modern science and engineering**, and his philosophical views continue to inspire and challenge us to this day.




☀ **Claudius Ptolemy**

**[85] Ptolemy**

Known for: Greco-Roman science

> *"I know that I am mortal by nature, and ephemeral; but when I trace at my pleasure the windings to and fro of the heavenly bodies I no longer touch the earth with my feet: I stand in the presence of Zeus himself and take my fill of ambrosia."*
>
> *— Ptolemy*

**[86] Joseph-Louis Gay-Lussac**

Birth: Dec. 6, 1778, Saint-Léonard-de-Noblat, France

Death: May 9, 1850, Paris

Known for: Behavior of gases

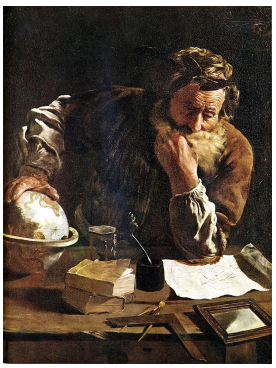


Joseph Louis Gay-Lussac

> *"In the natural sciences, and particularly in chemistry, generalities must come after the detailed knowledge of each fact and not before it."*
>
> *— Joseph-Louis Gay-Lussac*

**[87] Archimedes**

Known for: the Beginning of Science

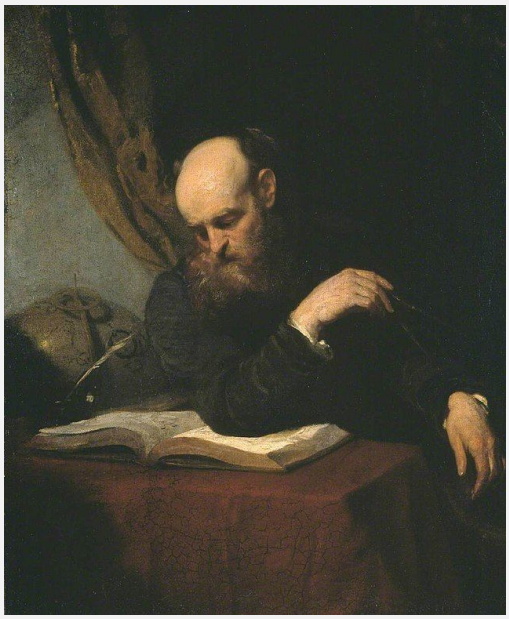


Archimedes of Syracuse

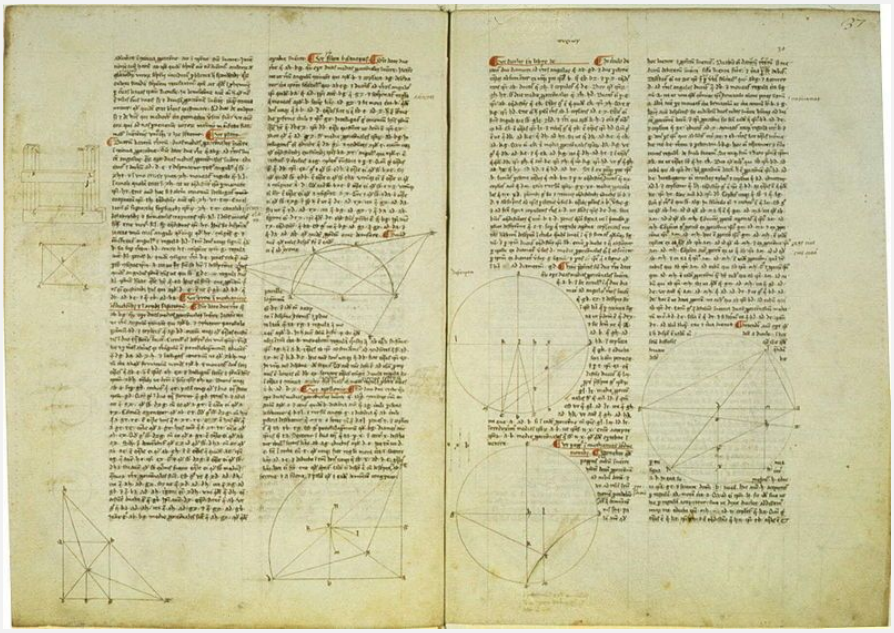


The Death of Archimedes (1815)

> *"Give me a place to stand and I will move the earth."*
>
> *— Archimedes*



**Archimedes** was a Greek mathematician, physicist, engineer, inventor, and astronomer who lived in Syracuse, Sicily, in the 3rd century BC. He is considered one of the greatest mathematicians of all time, and his contributions to the field of mathematics and physics are still studied today. **Archimedes** made significant contributions to geometry, including his famous principle of buoyancy, which states that the buoyant force on an object submerged in a fluid is equal to the weight of the fluid displaced by the object. He also developed the concept of the lever, which he famously stated, **"Give me a place to stand and I will move the earth."** **Archimedes** also made significant contributions to the field of mechanics, including the discovery of the principle of the lever, which he used to design and build machines such as pulleys and cranes. He also formulated a mathematical theory of hydrostatics, which allowed him to calculate the volumes and densities of different objects and liquids. In addition to his contributions to mathematics and physics, **Archimedes** also made important discoveries in the fields of astronomy, engineering, and military science. He is known for developing advanced war machines, including the famous **"Archimedes' screw,"** a device used to move water uphill, and for his work in designing defensive fortifications during the siege of Syracuse. **Archimedes** is considered one of the most important figures in the history of mathematics and science, and his work has influenced countless scientists and mathematicians throughout history.



A page from **"On the Sphere and Cylinder"**

This work of Archimedes discusses the properties of spheres and cylinders, including their volumes and surface areas.



Cicero Discovering the Tomb of Archimedes

**[88] Sir Fred Hoyle**

Birth: June 24, 1915, Bingley, Yorkshire [now West Yorkshire], England

Death: Aug. 20, 2001, Bournemouth, Dorset

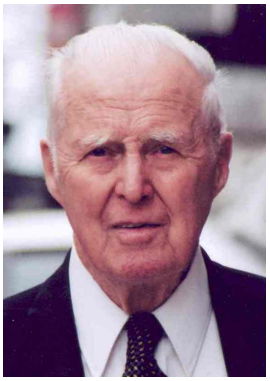
Known for: Stellar nucleosynthesis

> *"Space isn't remote at all. It's only an hour's drive away if your car could go straight upwards."*
>
> *— Fred Hoyle*

**[89] Norman Ernest Borlaug**

Birth: March 25, 1914, Cresco, Iowa, U.S.

Known for: Green revolution



Norman Borlaug, in 2004

> *"You can't build a peaceful world on empty stomachs and human misery."*
>
> *— Dr. Norman Ernest Borlaug*

**[90] Amedeo Avogadro**

Birth: Aug. 9, 1776, Turin, in the Kingdom of Sardinia and Piedmont

Death: July 9, 1856, Turin, Italy

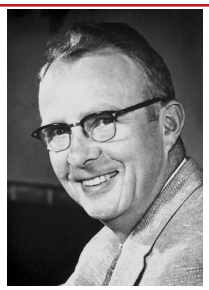
Known for: Molecular Hypothesis of Combining Gases



Amedeo Avogadro

*"We suppose ... that the constituent molecules of any simple gas whatever (i.e., the molecules which are at such a distance from each other that they cannot exercise their mutual action) are not formed of a solitary elementary molecule, but are made up of a certain number of these molecules united by attraction to form a single one."*

*— Count of Quaregna Amedeo Avogadro*



Luis Walter Alvarez

**[91] Luis W. Alvarez**

Birth: June 13, 1911, San Francisco, Calif., U.S.

Death: Sept. 1, 1988, Berkeley, California

Known for: discovery of many resonance particles (subatomic particles having extremely short lifetimes and occurring only in high-energy nuclear collisions)

*"Around the lab I heard that publicity was measured in an absolute unit, the "kan". That unit was too large for ordinary application and a practical unit one one-thousandth of the size served in its place, the "**millikan**"."*

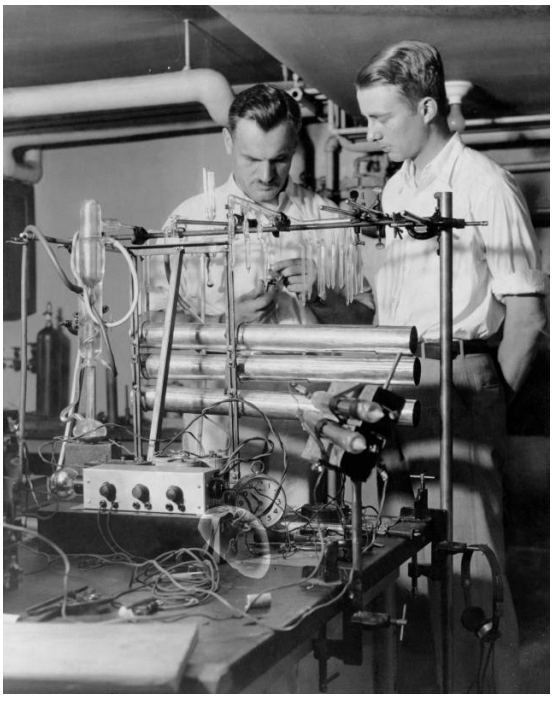
*— Luis W. Alvarez*

**[92] George Gamow**

Birth: March 4, 1904, Odessa, Russian Empire [now in Ukraine]

Death: Aug. 19, 1968, Boulder, Colo., U.S.

Known for: Big Bang Hypothesis



Nobel Laureate Arthur Compton, left, with young graduate student Luis Alvarez at the University of Chicago in 1933

*"It took less than an hour to make the atoms, a few hundred million years to make the stars and planets, but five billion years to make man!"*

*— George Gamow*



Francis Sellers Collins

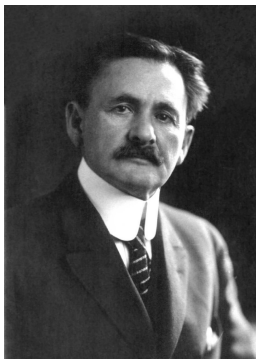
**[93] Francis Collins**

Birth: April 14, 1950, Staunton, Va., U.S.

Known for: Human Genome Project

*"Yeah, it's true we're all dealt a set of cards. But it's also true that it's up to us to figure out how to play the hand."*

*— Francis S. Collins*



**[94] Albert Abraham Michelson**

Birth: Dec. 19, 1852, Strelno, Prussia [now Strzelno, Pol.]

Death: May 9, 1931, Pasadena, Calif., U.S.

Known for: Establishment of the speed of light as a fundamental Constant



*"The velocity of light is one of the most important of the fundamental constants of Nature. Its measurement by Foucault and Fizeau gave as the result a speed greater in air than in water, thus deciding in favor of the undulatory and against the corpuscular theory. Again, the comparison of the electrostatic and the electromagnetic units gives as an experimental result a value remarkably close to the velocity of light–a result which justified Maxwell in concluding that light is the propagation of an electromagnetic disturbance. Finally, the principle of*

*relativity gives the velocity of light a still greater importance, since one of its fundamental postulates is the constancy of this velocity under all possible conditions."*

*— A.A. Michelson*

**[95] Rachel Carson**

Birth: May 27, 1907, Springdale, Pa., U.S.

Death: April 14, 1964, Silver Spring, Md.

Known for: Environmental pollution and the natural history of the sea



Carson in 1940

*"In nature nothing exists alone."*

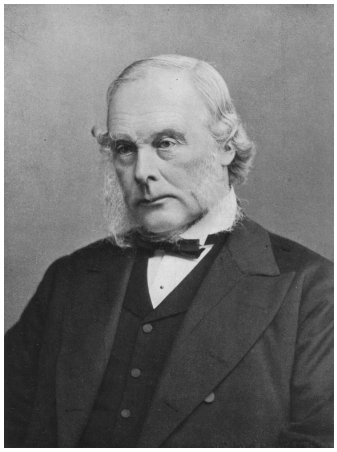
*— Rachel Carson*

**[96] Joseph Lister**

Birth: April 5, 1827, Upton, Essex, England

Death: Feb. 10, 1912, Walmer, Kent

Known for: antiseptic medicine



Joseph Lister

*"But when it has been shown by the researches of Pasteur that the septic property of the atmosphere depended not on the oxygen, or any gaseous constituent, but on minute organisms suspended in it, which owed their energy to their vitality, it occurred to me that decomposition in the injured part might be avoided without excluding the air, by applying as a dressing some material capable of destroying the life of the floating particles. Upon this principle I have based a practice."*

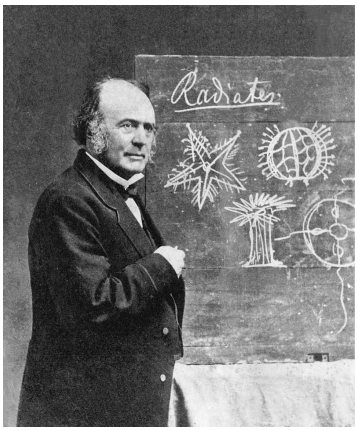
— *Joseph Lister*

**[97] Louis Agassiz**

Birth: May 28, 1807, Motier, Switz.

Death: Dec. 14, 1873, Cambridge, Mass., U.S.

Known for: Natural science




Agassiz in 1870

*"Every great scientific truth goes through three stages. First, people say it conflicts with the Bible. Next they say it has been discovered before. Lastly they say they always believed it."*

— *Louis Agassiz*

**[98] André-Marie Ampère**

Birth: Jan. 22, 1775, Lyon, France

Death: June 10, 1836, Marseille

Known for: Electrodynamics



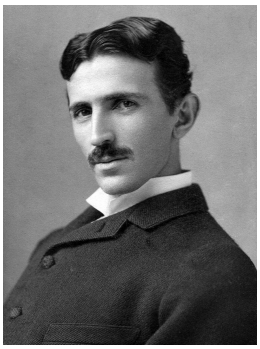
A. Ampère

*"The future science of government should be called 'la cybernétique' (1843)*

*{Coining the French word to mean 'the art of governing,' from the Greek (Kybernetes = navigator or steersman), subsequently adopted as cybernetics by Norbert Wiener for the field of control and communication theory.}"*

— *André-Marie Ampère*

**[99] Paracelsus**



Nikola Tesla

Birth: Nov. 11 or Dec. 17, 1493, Einsiedeln, Switzerland

Death: Sept. 24, 1541, Salzburg, Archbishopric of Salzburg [now in Austria]

Known for: Der grossen Wundartzney ("**Great Surgery Book**")

> *"All things are poisons, for there is nothing without poisonous qualities. It is only the dose which makes a thing poison."*
>
> *— Paracelsus*




Paracelsus

**[100] Edward O. Wilson**

Birth: April 15, 1452, Anchiano, near Vinci, Republic of Florence [now in Italy]

Death: June 10, 1929, Birmingham, Ala., U.S.

Known for: Sociobiology

> *"Destroying rainforest for economic gain is like burning a Renaissance painting to cook a meal."*
>
> *— E.O. Wilson*

## ✓ Nikola Tesla's Letter To His Mother

My dear mother, I feel sad and dreary when I think of you. I don't know how, but I feel that you are not well.I wish I could be beside you now mother, to bring you a glass of water. All these years that I had spent in the service of mankind brought me nothing but insults and humiliation. This morning I woke up early, just before the dawn, because I had heard something that I have been hearing through my dreams for quite some time now. I heard this voice that sang some beautiful chant, lament or even prayer in Moorish. When I came to my senses I realized that this voice came from everywhere and it was impossible to determine whether it was from within. I am afraid of loosing my mind. I cannot confide this to Doctor Lionel because I don't trust him anymore. I heard that he visited Mr. Edison two weeks ago...

Again my thoughts are of you, Mother, and again I feel that same restlessness and sorrow. I will write to the Patent office to speed up the realization of my public experiment for one week. I have to go back home, to my homeland, to You. I know now for sure that you are not well because once again I have heard that lamenting voice, but this time I was wide awake. I still haven't lost my sense.

I didn't write to the Patent office, one of their agents came and I told him about my intentions in person. He said he was sorry, but the dates could not be changed because all the congressmen have already determined them. I went down to the Waterfalls and told the boys to prepare the turbines and wait for my call tomorrow.

I have decided to provide the mankind with the gift it deserves and to return to Europe, to You, Mother. Governments here are the same as the ones back home. I have realized now, at the very end, that the mankind depends on governments and the individual cannot change the world on himself. But that strange voice still bothers me. I know it is connected to You, my experiment, with something transcendental...

Dear Mother, I leave for Yugoslavia tomorrow. Miss Nora went to the Port and bought me the ticket for Lisbon. From there I will go by train to Zurich, and then straight home. It will take me approximately ten days, no more than two weeks, to get home.

Today I have entered the Congressional office building and at the middle of the congressional session asked for couple of minutes of their time. They weren't very happy about it but they let me. I asked for the telephone to call the laboratory at Niagara falls. The boys over there activated the turbines and the Congress hall was lit up with my power, ten times stronger than the regular one, as I promised it would. I didn't care about their reactions at all. I instantly left the hall, because I didn't do all this for them , but for the mankind. In that very moment, when I was looking at the lightning bulb to shine with "my" wireless electricity, I realized that I wasn't the maker of all this.

I felt that someone or something was carrying it from Niagara falls to the Congress hall and that the law I thought I "invented" actually always existed. I was just the vessel blessed with inspiration to formulate and explain it to the mankind. Instead of triumph and happiness, some empty sorrow emerged. I realized that I had missed something big in my life. As If I had left something unrecognized completely. Some formula was within the grasp of my understanding and I have failed or didn't want to clarify it. That has to be connected to that Moorish lament, I am sure of it now...

This letter will never get to you, Mother. I don't know why I write it to you when you cannot read it...rest in peace Mother and please forgive me for choosing paths that had lead me away from you. I cannot even be there for your funeral. I read the telegram that informed me of your death and despise people who weren't ready to understand two years ago that electricity can be transferred without wires. Now, they have seen it but they won't use it for centuries to come because someone burned my downtown laboratory to the ground, with all of my formulas and writings in it. They suspect of Mr. Edison. I became so indifferent, I cannot even recognize myself. I would maybe feel sad before but not any more because I am now sure that someone is keeping "my" patents under control, that "my" discovery isn't "mine" at all and finally, that mankind was not ready for it. I know that someone is overseeing everything and has a plan of their own, which is probably why I am indifferent.

My ship for Lisbon leaves at 11 o'clock. The car is waiting outside.

I will lay this letter on your grave, when I arrive at our village's graveyard. I believe in something that I have never believed at. I believe that I am still a part of you, and that my life is not over for good. I now feel sorry for avoiding Turks because they sang similar laments I heard before dawns. I now realize that they knew about this things a lot more than I ever did.

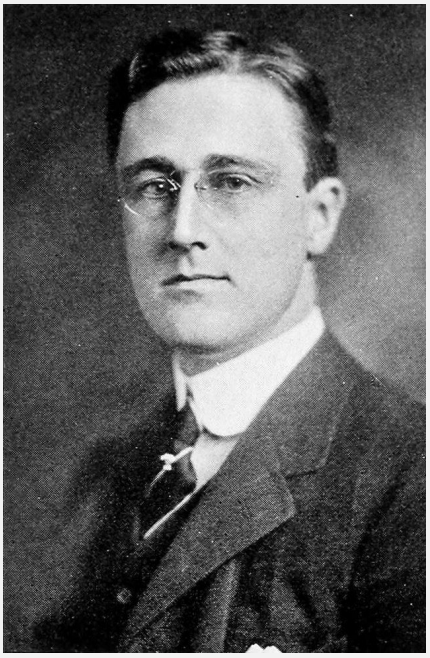
All those years spent in science were in vain. Please mother, pray for me over there if you can, sing the Moorish lament for the lost soul of your poor ignorant son...

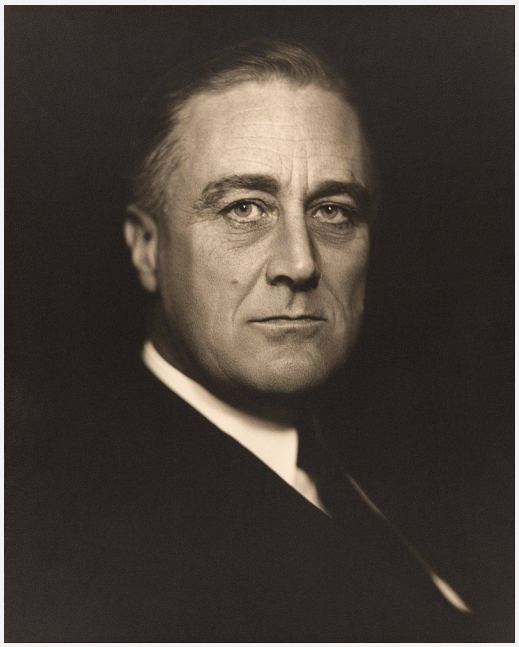
My mother forgave me for taking my paths from Thee, so I can not come to the funeral. Pray there, for me, Mother, if you can.



**This is the last letter by the famous Serbian scientist Nikola Tesla to his mother, Djuka.**

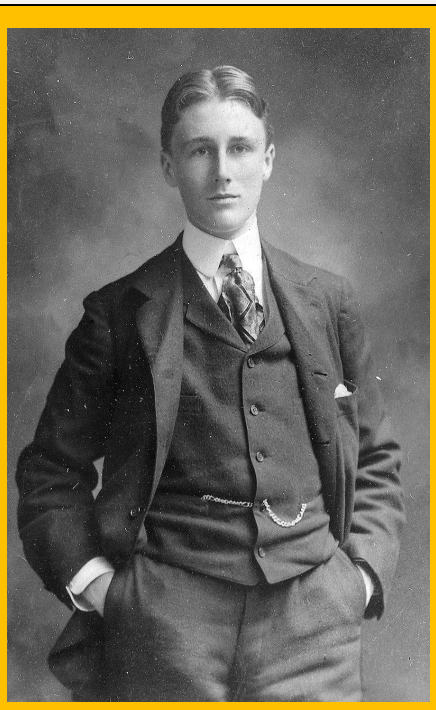
✓ **Letter, Franklin Roosevelt to Robert Oppenheimer thanking the physicist and his colleagues for their ongoing secret atomic research, 29 June 1943**







Roosevelt in 1893, at the age of 11



Roosevelt in 1900, at the age of 18

**THE WHITE HOUSE**

**WASHINGTON**

**June 29, 1943**

**SECRET**

My dear Dr. Oppenheimer:

I have recently reviewed with Dr. Bush the highly important and secret program of research, development and manufacture with which you are familiar. I was very glad to hear of the excellent work which is being done in a number of places in this country under the immediate supervision of General L.R. Groves and the general direction of the Committee of which Dr. Bush is Chairman. The successful solution of the problem is of the utmost importance to the national safety, and I am confident that the work will be completed in as short a time as possible as the result of the wholehearted cooperation of all concerned.

I am writing to you as the leader of one group which is to play a vital role in the months ahead. I know that you and your colleagues are working on a hazardous matter under unusual circumstances. The fact that the outcome of your labors is of such great significance to the nation requires that this program be even more drastically guarded than other highly secret war development. I have therefore given directions that every precaution be taken to insure the security of your project and feel sure that those in charge will see that these orders are carried out. You are fully aware of the reasons why your endeavors and those of your associates must be circumscribed by very special restrictions. Nevertheless, I wish you would express to the scientists assembled with you my deep appreciation of their willingness to undertake the tasks which lie before them in spite of the dangers and the personal sacrifices. I am sure that we can rely on their continued wholehearted and unselfish labors. Whatever the enemy may be planning, American science will be equal to the challenge. With this thought in mind, I send this note of confidence and appreciation.

Though there are other important groups at work, I am writing only to you as the leader of one which is operating under very special conditions, and to General Groves. While this letter is secret, the contents of it may be disclosed to your associates under pledge of secrecy.

Very Sincerely Yours

Franklin Delano Roosevelt

**Dr. J. R. Oppenheimer**

**Post Office Box 1663**

**Santa Fe,**

**New Mexico**

The orbital angular velocity (ω) of a satellite of mass (m) moving in a circular orbit of radius (r) around the earth of mass (M) is given by:

$$\omega = \sqrt{\frac{GM}{r^3}}$$

The angular velocity of the Earth's rotation is given by:

$$\omega = \frac{2\pi}{24 \times 60 \times 60} = 7.27 \times 10^{-5} \text{ rad/s}$$

If the satellite's orbital angular velocity matches the Earth's angular velocity of rotation, it means that the satellite completes one orbit in the same amount of time it takes for the Earth to complete one rotation.

$$\sqrt{\frac{GM}{r^3}} = 7.27 \times 10^{-5} \text{ rad/s}$$

$$r = \sqrt{\frac{6.673 \times 10^{-11} \text{Nm}^2/\text{kg}^2 \times 5.97 \times 10^{24} \text{ kg}}{(7.27 \times 10^{-5} \text{ rad/s})^2}} \approx 4.22 \times 10^7 \text{m}$$

**The radius of a geosynchronous orbit.**

## Astrolinguistics:

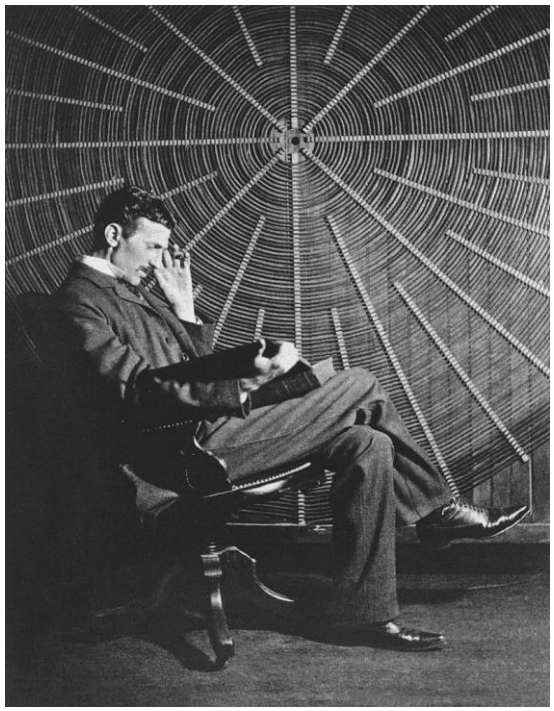
A **hypothetical field of study** that combines the disciplines of **linguistics** and **astronomy**. It explores the possibility of extraterrestrial languages and communication systems that might exist in the universe.

## Types of Elementary particles

- ✓ Fermions → quarks + leptons
- ✓ Bosons (force carriers) → photons + gluons + gravitons

**Massless** → moves at speed of light

**High mass** → moves at less than speed of light



**Tesla sitting in front of a spiral coil used in his wireless power experiments at his East Houston St. laboratory.**

The luminosity of the sun is the amount of energy it emits per second. The product of the sun's luminosity and age determines how much energy the sun produces over the course of its four and a half billion year existence (remember 1 year equals $3 \times 10^7$ seconds):

E = solar luminosity × age of the sun = $4 \times 10^{33}$ watts × $(4.5 \times 10^9 \times 3 \times 10^7)$ seconds

☀ $E = 5.4 \times 10^{50}$ erg

The total energy the sun emits during its lifetime of four and a half billion years is $5.4 \times 10^{50}$ erg

**A star like the sun contracts, releasing gravitational energy that is converted into thermal energy, which causes the star to heat up**

$$\text{Gravitational binding energy of the sun} \approx \frac{3GM_{sun}^2}{5R_{sun}} \approx 2.4 \times 10^{48} \text{ erg}$$

where G is the gravitational constant. The sun's gravitational binding energy is obviously 100 times too small compared to the total amount of energy it produces over the course of its four and a half billion year existence.

☀ **The nature's most tightly bonded nucleus is $Fe^{56}$**

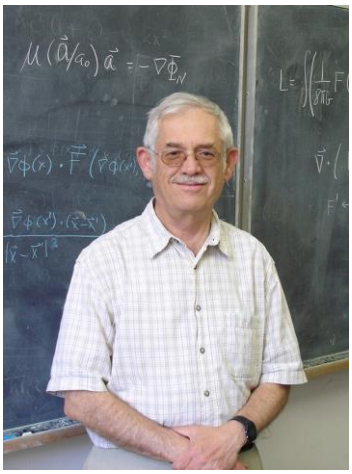
**In nature, there are only three light neutrinos. The direct observation of the third neutrino, known as tau-neutrino, was confirmed several years later in 2000 at Fermilab by the DONUT experiment. The first two, electron-neutrino and muon-neutrino, were already known.**

- The electromagnetic force at action in atomic structures is much simpler than the nuclear forces that hold nucleons together.
- One of **Hans Bethe's key discoveries**, as noted in his Nobel citation, concerned the exact fusion events occurring in **stars** (which serve as the basic building elements of galaxies).

- The **nuclear shell model**, used to describe the structure of the atomic nucleus in terms of energy levels, is a model of the atomic nucleus that is based on the **Pauli Exclusion Principle**. The shell model has been quite effective at explaining a variety of nuclear features.
- Since matter, not anti-matter, dominates our cosmos, we are aware of this. That is a very implausible scenario for how the cosmos began. **What forces led to the asymmetry that we observe today if our universe initially contained an equal amount of matter and antimatter?** Although we do not understand the fundamental forces, we do understand that a violation of **Charge Conjugation Parity symmetry** is a necessary component.

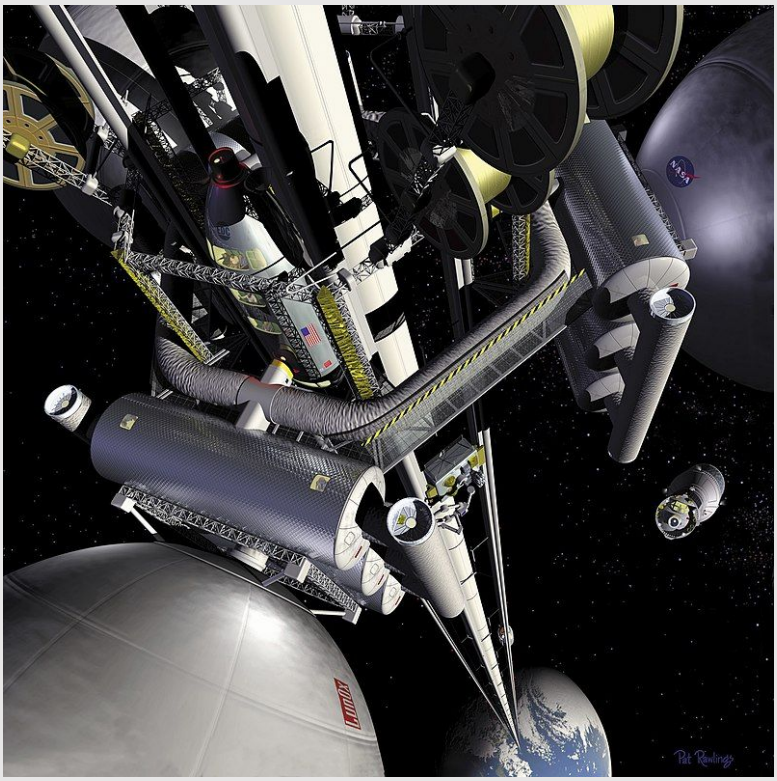
**A massive star's implosion may produce a black hole, which is a super dense entity. During this process, its gravitational field intensifies to the point where its escape velocity is faster than the speed of light.**

**Stephen Hawking** demonstrated in 1971 that the combined event horizon area of two collapsing black holes exceeds the sum of their individual event horizon areas using the theory of classical general relativity.



**Jacob Bekenstein claimed that black holes do have thermodynamic entropy proportional to the horizon area, drawing on the Hawking area theorem as inspiration.**

|  | **Example** |
|---|---|
| **Translational motion** | The motion of a bullet fired from a gun |
| **Rotational motion** | The motion of a spinning top |
| **Oscillatory motion** | The motion of a pendulum |
| **Circular motion** | The motion of the Moon around the Earth |

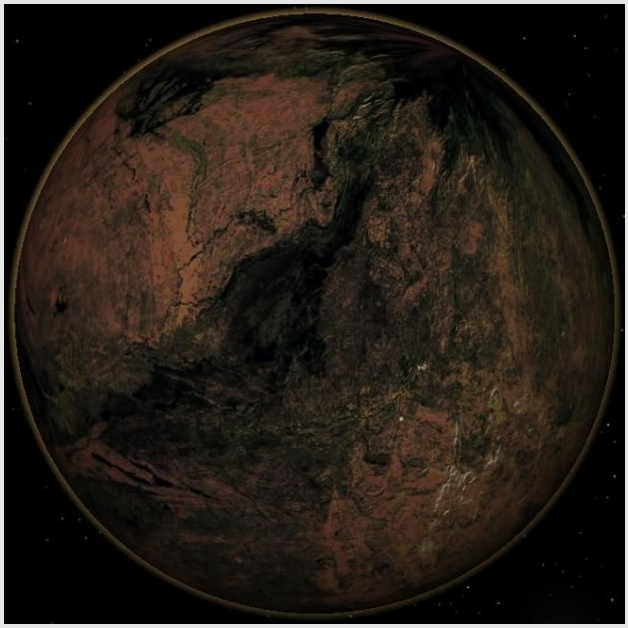


Artistic conception of a **space elevator** as viewed from the **geostationary transfer station**, the view extends along the length of the space elevator, descending towards the Earth.

A **hypothetical structure** consisting of a **long, strong cable** extending from the Earth's surface into space that would allow people, vehicles and payloads to travel from the Earth's surface to space without the **need for rockets**. This concept was first proposed by Russian scientist **Konstantin Tsiolkovsky** in 1895 and later popularized by **Arthur C. Clarke** in his science fiction novel **"The Fountains of Paradise."**

## Carbon planet

A hypothetical planet that contains more carbon than oxygen.



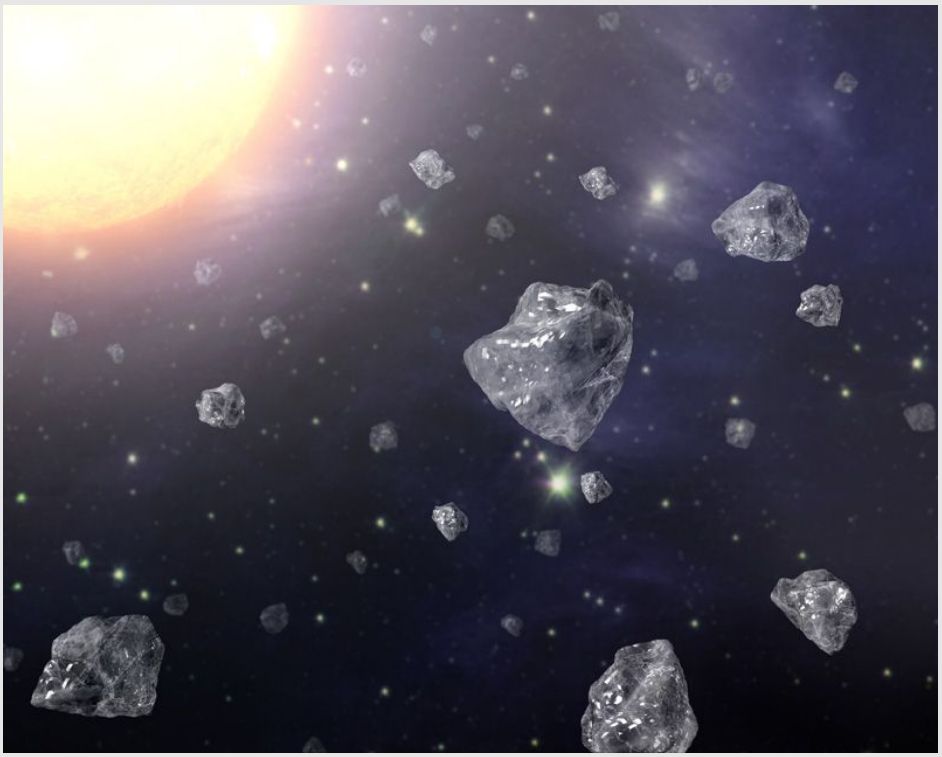
This artistic depiction portrays a **carbon planet**, where its surface appears dark and reddish due to the presence of extensive hydrocarbon deposits.

## Iron planet

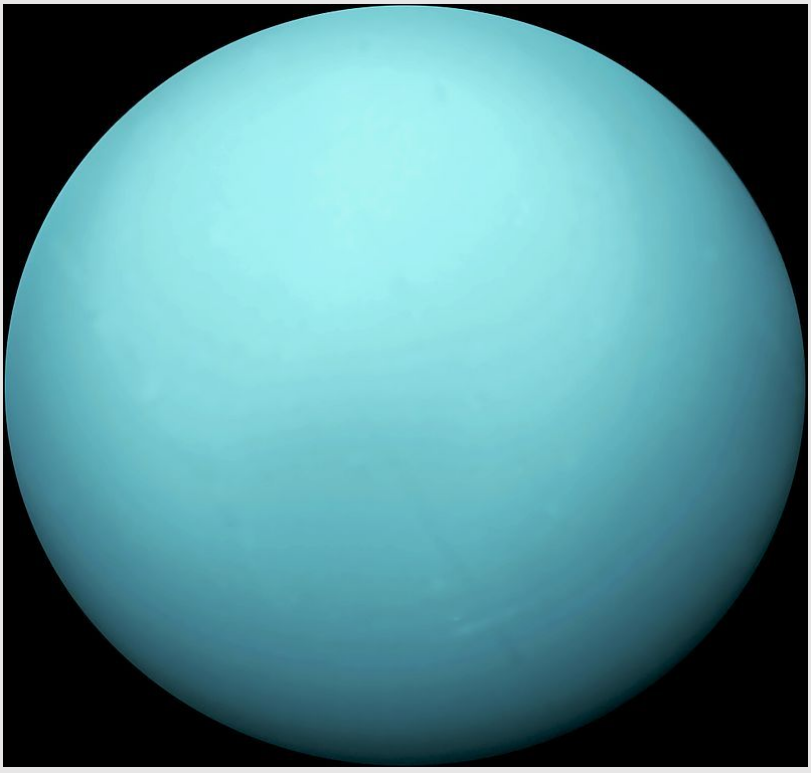
A type of planet that is characterized by a predominant composition, featuring an iron-rich core and typically possessing a little or no mantle layer.

## Desert planet

A rocky planet that is known for its scarcity of water. It is characterized by arid, dry landscapes similar to Earth's hot deserts.



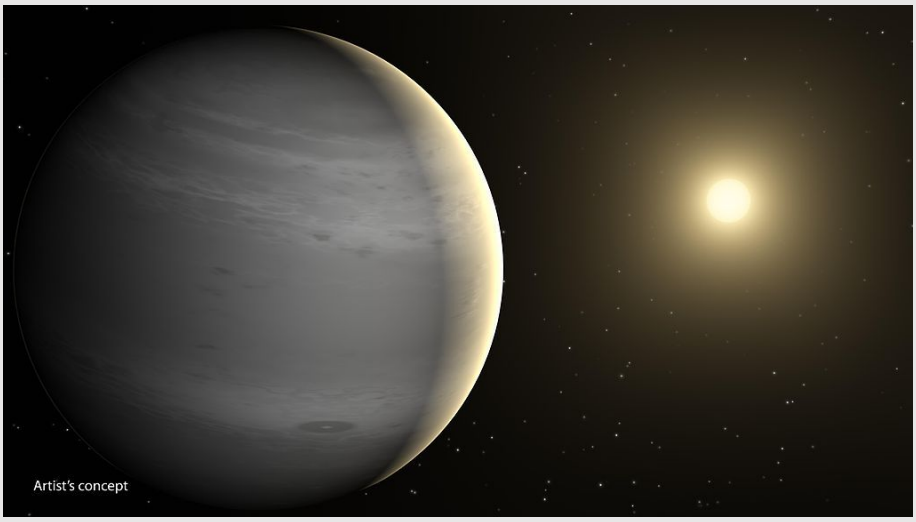
Artistic depiction of a **plethora of tiny diamonds** next to a hot star.



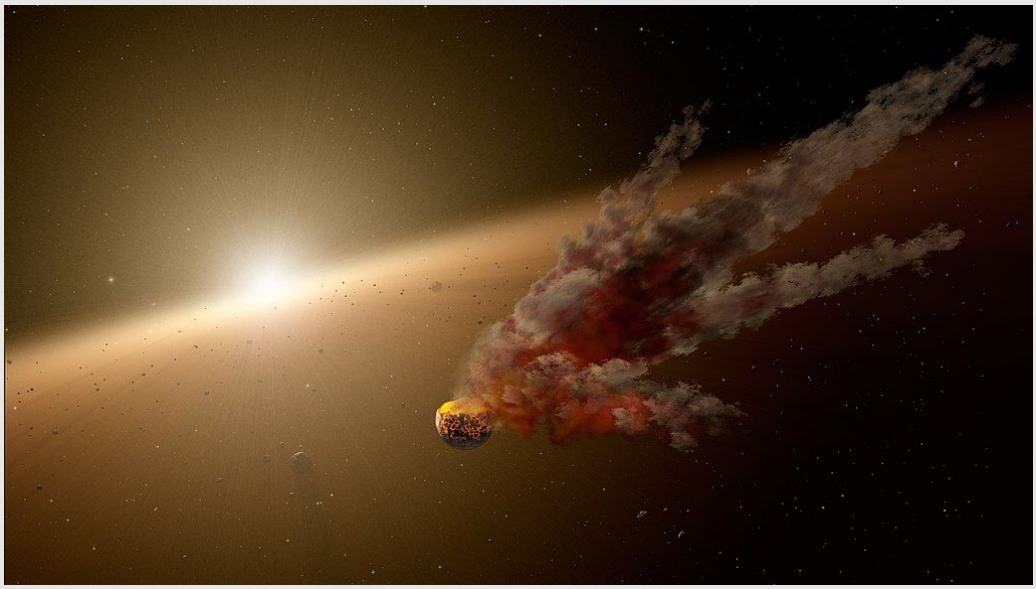
The image of **Uranus** taken by the **Voyager 2** spacecraft in 1986.

## Helium planet

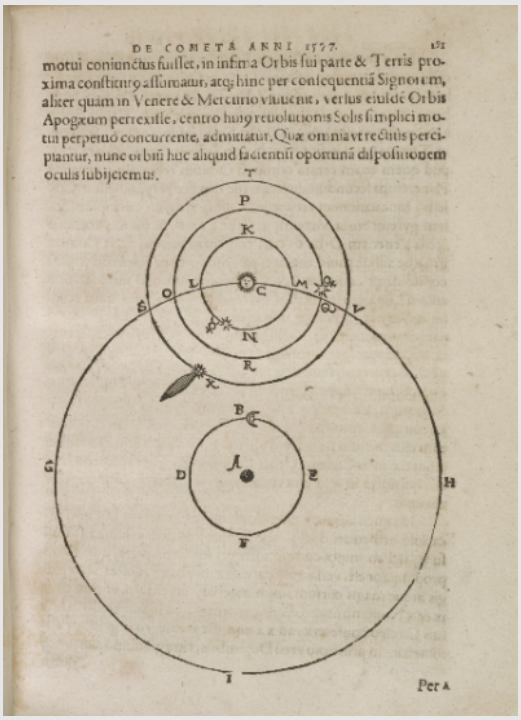
A type of **planet** characterized by having an atmosphere predominantly composed of **helium**.




In this artistic conception, **Helium planet** is depicted with a white or grey hue. This planet completes one orbit around its star every 2.6 days, and its star has a cooler temperature compared to our sun, giving it a **yellow-orange** hue.



Artistic conception of **asteroids** colliding during **planet formation.**


DE COMETA ANNI 1577. 121

motui coniunctus fuiſſet, in infima Orbis ſui parte & Terris proxima conſtituto aſſimilatur, atq; hinc per conſequentiã Signorem, aliter quam in Venere & Mercurio vitiatur, verſus eiuſdé Orbis Apogæum perrexiſſe, centro huius reuolutionis Solis ſimplici motui perpetuò concurrente, admittatur. Quæ omnia vt rectius percipiantur, nunc orbiũ huc aliquid facientiũ oportunã diſpoſitionem oculis ſubijciemus.



**Tycho Brahe**

Page from a treatise by **Tycho Brahe** depicting his geocentric view of the **Great Comet of 1577.**



A **collision** between two **planetary bodies** as imagined by an artist. The **Moon** was most likely created by such a **collision** between **Earth** and a **Mars-sized** asteroid.

# Phaeton hypothesis

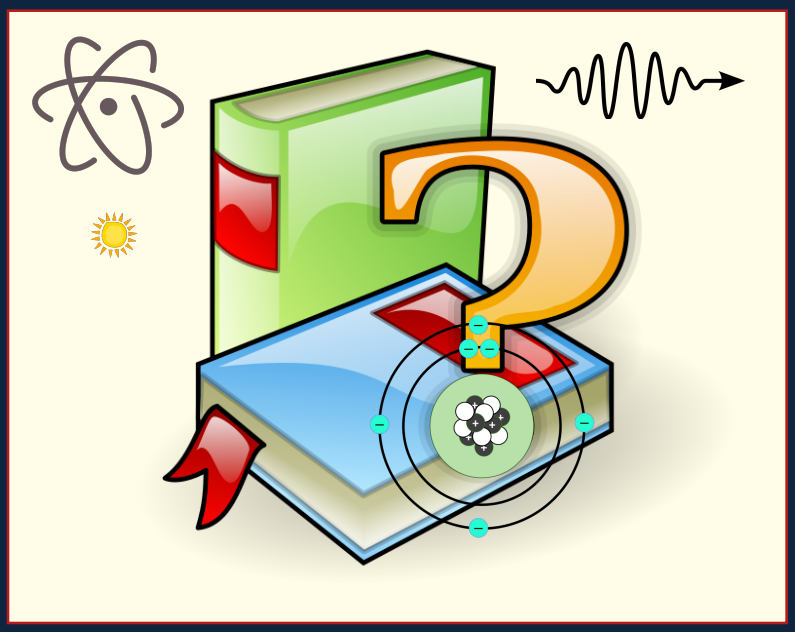
An older scientific concept that suggests the existence of a hypothetical planet named **Phaeton**, which is believed to have once existed in the early solar system (i.e., in the region where the **asteroid belt** now resides). It is speculated that a **catastrophic event**, such as a massive collision or gravitational perturbation, caused **Phaeton** to be shattered into numerous fragments, giving rise to the **asteroid belt** as we observe it today.



**Heinrich Wilhelm Matthäus Olbers**

A German astronomer, physician and physicist who formulated the **planet Phaeton hypothesis**.

**Since the last few decades, it has been difficult to comprehend the accelerated cosmic expansion and the source of dark energy. A basic principle that can explain dark energy and produce a workable cosmology is still missing.**



The two stone foundations that support a large portion of current physics are quantum physics and Albert Einstein's theory of general relativity. The connection between these two accepted ideas is still a key unresolved issue in theoretical physics.

## ✓ Virial temperature

The typical temperature at which a system that is gravitationally bound would satisfy the **Virial Theorem**

To remain connected to one another inside a nucleon, quarks exchange gluons. The spin-1 gluons are hence strong interaction mediators. Photons only interact with quarks and not with gluons because gluons lack an electric charge.

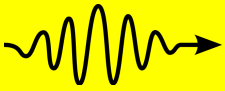
**In just ten seconds, gamma-ray bursts can release more energy than our Sun would in its whole lifetime.**

**The earliest stars are thought to have formed some 200 million years after the Big Bang, according to experts.**

## SCHRÖDINGER'S CAT PARADOX

If you put a cat and a poison that could kill it in a box and seal it, you won't know whether the cat is dead or alive until you open the box, thus up until that moment, the cat seems to be "dead and alive."

**… Thus, Einstein's original gravity equation was correct, and changing it was a mistake. Much later, when I was discussing cosmological problems with Einstein, he remarked that the introduction of the cosmological term was the biggest blunder he ever made in his life. But this "blunder", rejected by Einstein, is still sometimes used by cosmologists even today, and the cosmological constant L rears its ugly head again and again and again.**



**– George Gamow** (1904–1968) in **"My World Line"** p.44

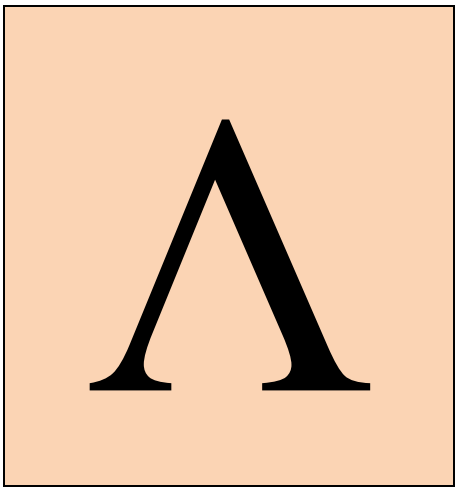
**The age of a flat universe:**

$$t_{age} = \frac{2}{3H} < \mathbf{10\ Gyr}$$

**Yet** some stars (*e.g.,* globular clusters, quasars...) are estimated to be as old as 12.5 Gyr.

## The Cosmological Constant

If the cosmological constant were even slightly larger, it would have prevented the formation of galaxies and stars in the early universe.

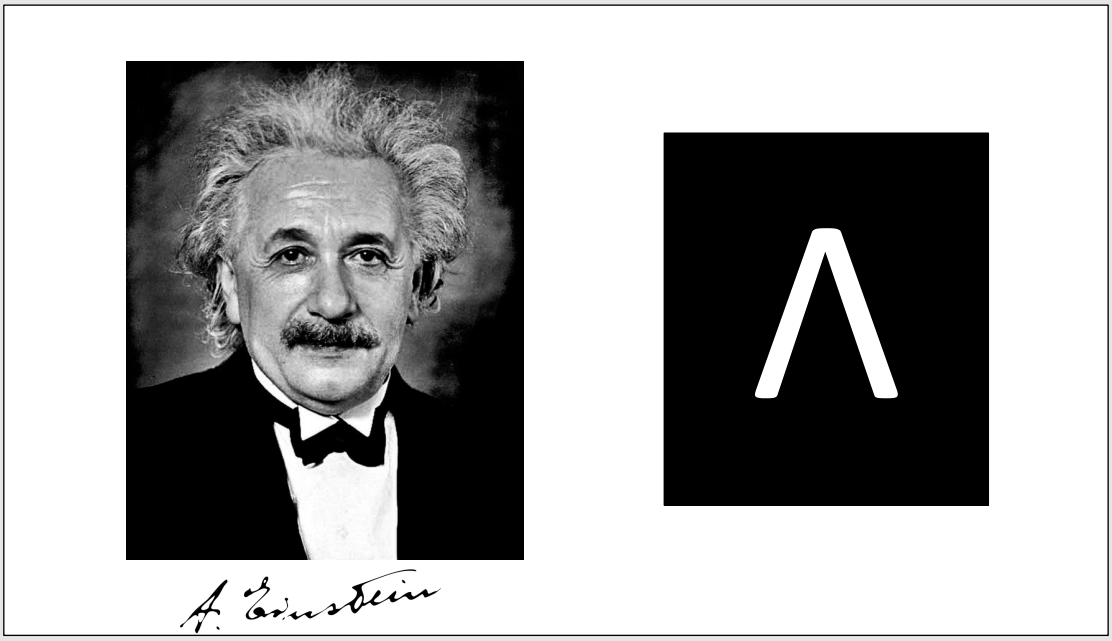


A large $\Lambda$ is needed to have the inflation epoch.

A small $\Lambda$, the dark energy, fits snugly with the inflation cosmology prediction of a **flat universe** solving the missing energy and cosmic age problems.

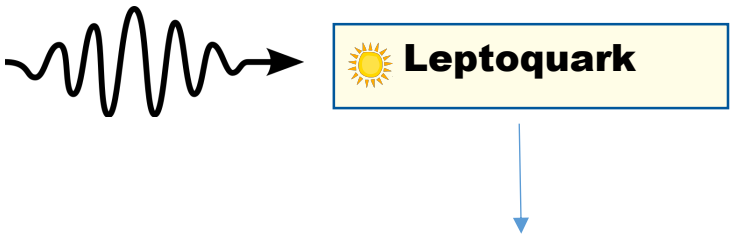
A black hole with the mass of the sun will have a Hawking temperature of $10^{-8}$ K, while one with the mass of the earth will have a Hawking temperature of 0.1 K.

✓ **Dark energy** and the **cosmological constant** are both concepts used in **modern** physics and **cosmology** to explain the accelerating expansion of the universe.

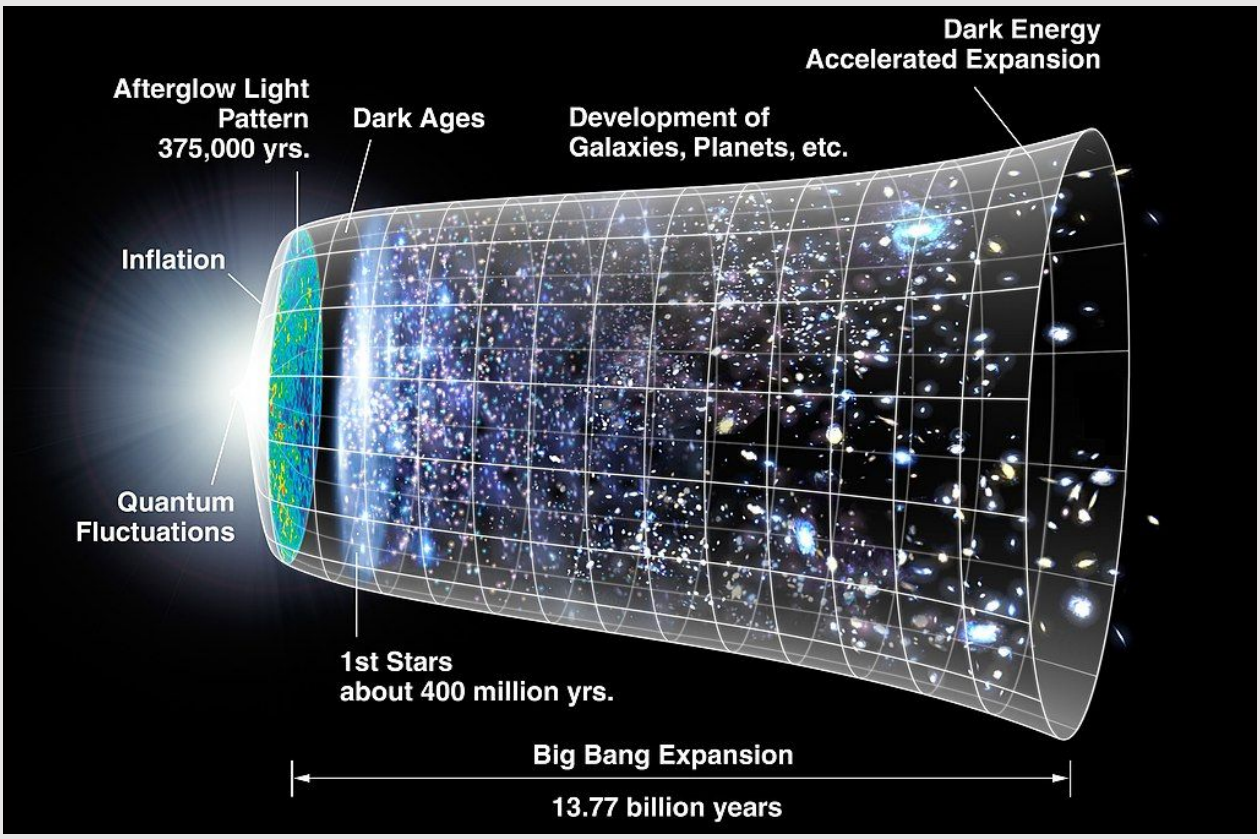



The **cosmological constant** (Λ) is a term that **Einstein** introduced into his equations of **general relativity** to describe a **constant energy density** that would provide a balance to gravity and keep the universe static. Later, when it was discovered that the universe is actually expanding, the **cosmological constant** was abandoned as unnecessary. **Einstein** referred to the introduction of the cosmological constant as his **"greatest blunder"** because it had prevented him from predicting the expanding universe. However, it was resurrected in the late 1990s as a way to explain the observed accelerating expansion of the universe. **Dark energy** is a term used to describe the **unknown force** or **energy** that is thought to be causing the accelerating expansion of the universe. It is called **"dark"** because it is not directly observable, but its effects can be seen through its impact on the **large-scale structure of the universe** and the **cosmic microwave background radiation**. The nature of **dark energy** and the **cosmological constant** poses significant challenges to our understanding of fundamental physics. One of the central questions is why the cosmological constant has such a small but non-zero value. The observed value is approximately $10^{-52}$ $m^{-2}$, which is extraordinarily tiny compared to theoretical predictions based on **quantum field theory**. This discrepancy is known as the **cosmological constant problem** and it remains one of the biggest mysteries in physics and cosmology. The **cosmological constant** and **dark energy** are closely related. In the framework

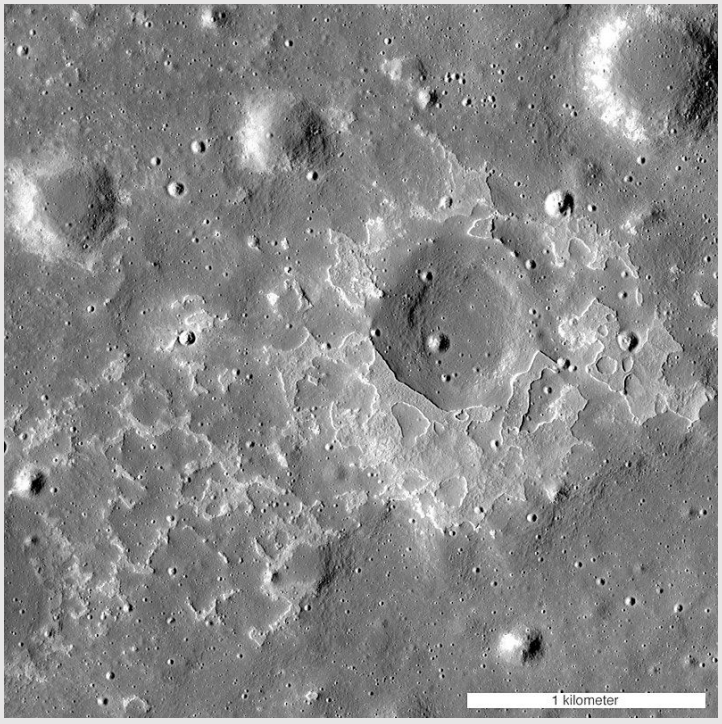
of **general relativity**, the **cosmological constant** is mathematically equivalent to a form of **energy density** inherent in empty space. This **energy density** exerts a negative pressure, causing a repulsive gravitational effect that counteracts the attractive force of matter. This repulsive effect leads to the acceleration of the universe's expansion. Understanding dark energy is of paramount importance in unravelling the mysteries of the universe's past, present, and future. The properties of **dark energy** play a critical role in shaping the fate of our cosmos. One possible scenario for the universe's future, based on our current understanding, is **that dark energy** will continue to drive the accelerated expansion indefinitely. In this case, the expansion rate would gradually increase over time, leading to the eventual dispersal of galaxies and a state known as the **"heat death"** or **"big freeze."** In this scenario, the universe would become increasingly sparse and cold, making it **inhospitable** for the formation of new stars and galaxies. However, there are other potential outcomes depending on the properties of **dark energy**. One intriguing possibility is the occurrence of a **"big rip."** If **dark energy** possesses unusual characteristics, such as an increasing in strength over time, it could eventually overpower the gravitational forces holding galaxies, stars, and even atoms together. The universe would undergo a **catastrophic event** where everything, from cosmic structures to subatomic particles, would be torn apart. Another scenario is the **"big crunch."** If **dark energy** evolves in a way that its repulsive effect weakens over time, the universe's expansion could slow down and eventually reverse. **Gravity** would dominate, causing the universe to contract and ultimately collapse in a fiery event, returning all matter and energy to a **singularit**y. These potential futures highlight the delicate balance between **dark energy** and the **gravitational forces** acting within the universe. Determining the nature of **dark energy** and its evolution is crucial for understanding which scenario, among many possibilities, is most likely to unfold.



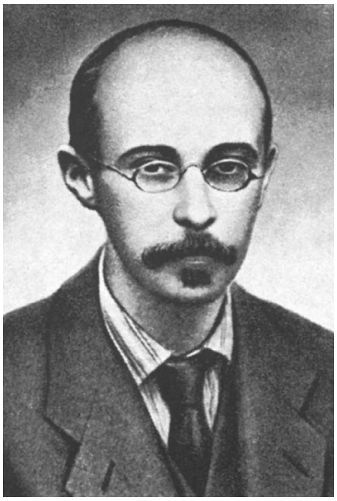

A hypothetical fundamental particle with properties of both **quarks** and **leptons**, which would decay into **quarks** and **leptons**, might assist to explain why there are three generations of leptons and quarks in the **standard model of physics**. Despite rigorous experiments conducted at **Fermilab**, no evidence of **leptoquark** has been found thus far.




**A representation of the evolution of the universe over a span of 13.77 billion years.**




**Volcanic deposits** on the Moon are evidence of past volcanic activity on Earth's natural satellite.



Alexander Friedmann

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(\rho + \frac{3P}{c^2}\right) + \frac{\Lambda}{3}c^2$$

Slows down expansion

Speeds up expansion

**Friedmann equation**

"Chemistry, like all other sciences, had arisen from the reflections of ingenious men on general facts, which occur in the practice of the various arts of common life."

– **Joseph Black**

"As dangerous as is the desire to systematize in the physical sciences, it is, nevertheless, to be feared that in storing without order a great multiplicity of experiments we observe the science rather than clarify it, render it difficult of access to those desirous of entering upon it, and finally, obtain at the price of long and tiresome work only disorder and confusion. Facts, observations, experiments—these are the materials of a great edifice, but in essembling them we must combine them into clusters, distinguish which belongs to which order and which part of the whole each pertains."

**Lavoisier in his Memoir on Combustion in General (1777)**

$\frac{8\pi G}{c^4}$ = Einstein gravitational constant

Einstein gravitational constant × Planck force = $8\pi$

**Halley's Comet is one of the most well-known comets and has significant historical significance. During its near flyby of Earth, which occurs every 76 years, it is visible to anyone on the planet.**

| ✓ Theory of relativity | ✓ Quantum mechanics |
|---|---|
| • Eliminates inconsistencies in the classical theory.<br>• Portrays the behavior of matter at high energies and high speeds ($v \approx c$). | • Eliminates conflicts between theory and measurements.<br>• Portrays the behavior of infinitesimal particles. |

**Classical physics** → non-relativistic ($v << c$) limit

**Quantum Mechanics**

- Wave-particle duality
- Superposition
- Probabilities

**Special Relativity**

- Spacetime geometry
- Relativity of motion

**Newtonian Mechanics**

- Universal gravitation
- Force and acceleration

The **cosmological constant** is a term in the equations of general relativity that represents a form of energy density that is constant throughout space and time.

↓

The **cosmological constant** was first introduced by **Albert Einstein** in 1917 as a way to modify his equations of general relativity to allow for a static universe.

↓

In the 1920s, **Edwin Hubble** discovered that the universe was expanding, and this led to the abandonment of the idea of a static universe.

↓

Einstein later called the introduction of the **cosmological constant** his **"greatest blunder"** because it was not needed to explain the expanding universe.

## Deceleration parameter

$$\frac{dH}{dt} = -H^2 (1 + q_0)$$

The **deceleration parameter**, denoted as $q_0$, is a measure of the rate at which the expansion of the universe is slowing down due to the gravitational attraction between all matter and energy in the universe. In simple terms, the deceleration parameter tells us whether the universe is speeding up, slowing down, or staying constant in its expansion. A **positive value of $q_0$** indicates that the expansion is decelerating, while a **negative value** indicates that the expansion is accelerating. A **value of $q_0$ equal to zero** corresponds to a universe expanding at a constant rate.



**Albert and Elsa Einstein in Japan, November-December 1922**





**Robert Oppenheimer** as Ph.D. student in Göttingen, Germany

**Zionist leaders Ben-Zion Mossison, Menachem Ussishkin, Chaim Weizmann with Albert Einstein.**

**Quantum Field Theory**

- Virtual particles
- Color charge
- Wave function

**General Relativity**

- Equivalence principle
- Dynamic spacetime

## Classical mechanics

Wave → Superposition

Particle → Position → Proton

## Quantum mechanics

Proton

Wave ↔ Particle

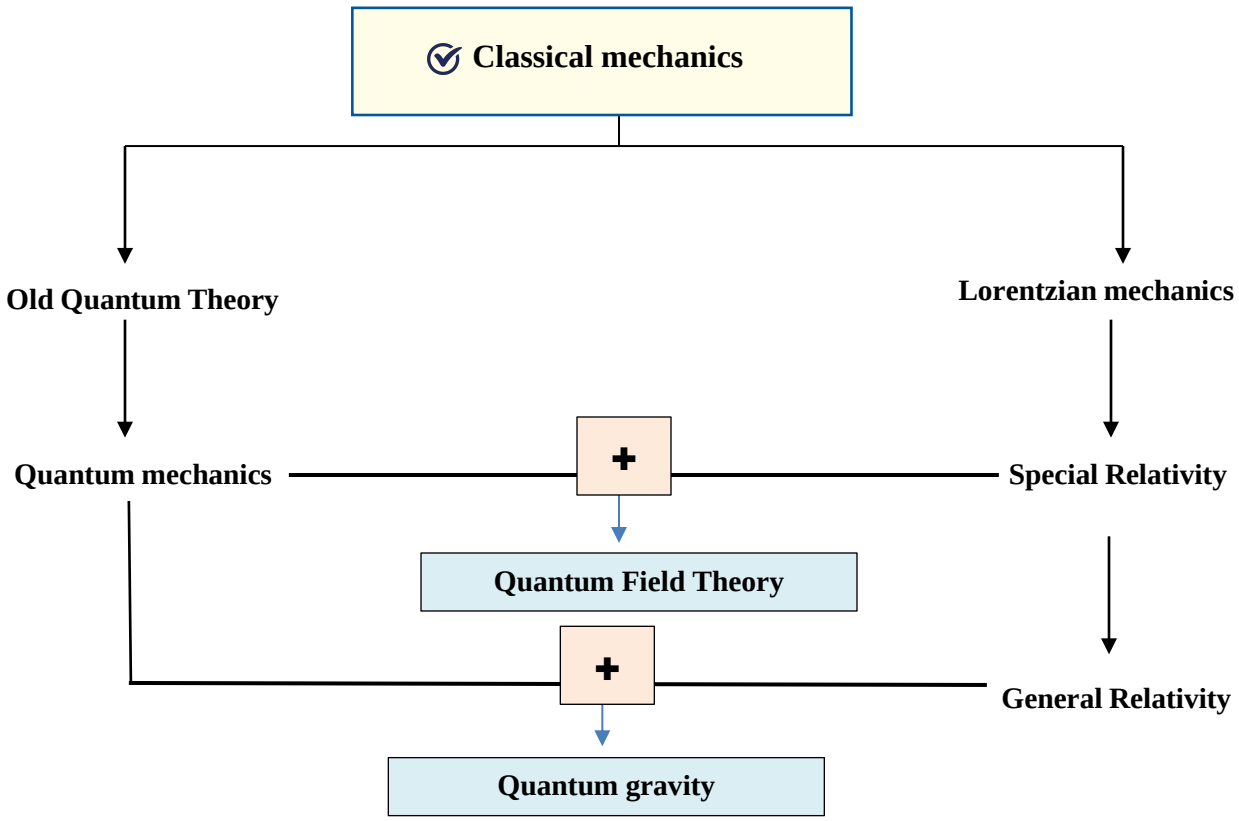
Wave → Superposition

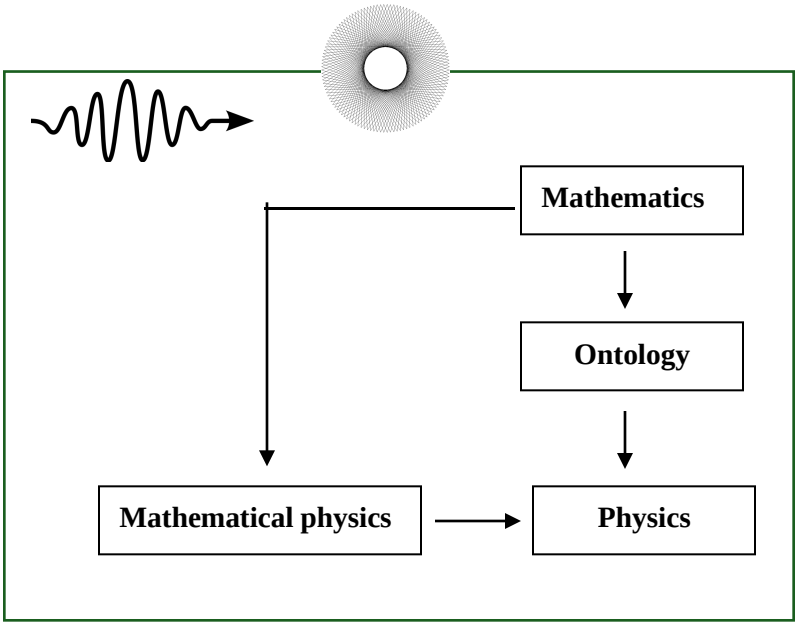
Particle → Position

| Quantum Physics | Quantum Mechanics |
|---|---|
| Describe the properties of a physical system | Describe the properties of molecules, atoms and subatomic particles |

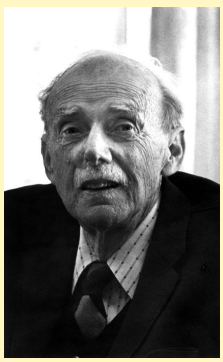
**Mechanics**
(Study of motion)

- **Kinematics** (Describes motion)
- **Dynamics** (Causes of motion)




"In science one tries to tell people, in such a way as to be understood by everyone, something that no one ever knew before. But in poetry, it's the exact opposite."



**— Paul Dirac**

Because of the intra-atomic movement of electrons, the atom must radiate not only electromagnetic but also gravitational energy, if only in minute amounts. Since, in reality, this cannot be the case in nature, then it appears that the quantum theory must modify not only Maxwell's electrodynamics but also the new theory of gravitation. **(Einstein 1916, p. 696)**

## Koide formula:

$$\frac{m_e + m_\mu + m_\tau}{(\sqrt{m_e} + \sqrt{m_\mu} + \sqrt{m_\tau})^2} = 0.666661 \approx \frac{2}{3}$$

This formula is an empirical relationship, meaning it was initially derived by fitting experimental data rather than being based on fundamental theoretical principles.

where $m_e$, $m_\mu$ and $m_\tau$ denote the masses of the electron, muon and tau.

- $m_e = 0.510998946\ MeV/c^2$
- $m_\mu = 105.6583745\ MeV/c^2$
- $m_\tau = 1776.86\ MeV/c^2$

## Warp drive

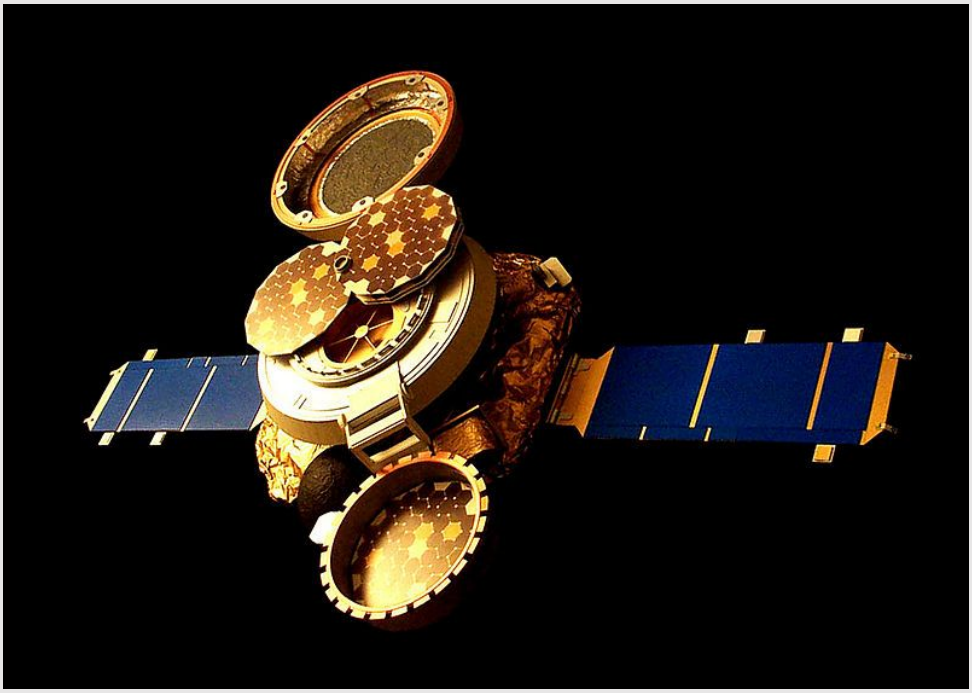
A theoretical propulsion system that could enable faster-than-light travel by distorting the fabric of space-time. It works by creating a **"warp bubble"** around a spacecraft, contracting space in front of it and expanding space behind it. This allows the spacecraft to effectively bypass the speed-of-light limitation and travel great distances in shorter times.



Artistic conception showing sand-laden jets erupt from geysers on Mars.



A patch of soil on Mars with a high concentration of silica discovered by the **Spirit rover**, part of **NASA's Mars Exploration Rover mission**, in 2007.



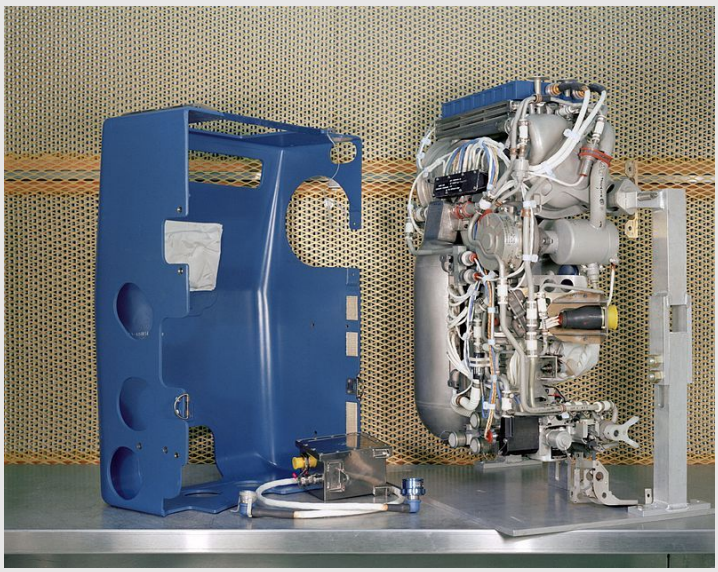
An artistic depiction of **Genesis spacecraft** in its active state of collecting and storing samples of solar wind particles.

## Extraterrestrial sample curation

The **processes** and **protocols** involved in the **handling**, **storage**, **analysis**, and **preservation** of **samples** collected from celestial bodies other than Earth. These **samples** can include rocks, soils, gases, ice, or other materials gathered from the Moon, asteroids, comets, or other planets and moons.

## Planetary surface construction

The processes and techniques involved in creating structures, artificial habitats, or infrastructure on the surface of celestial bodies such as planets, moons, or asteroids.



**The Apollo Portable Life Support System (PLSS)**

A crucial component of the spacesuit used by astronauts during the Apollo missions to the Moon. The **PLSS** provided life-sustaining resources, including oxygen, cooling, and environmental control, enabling astronauts to explore the lunar surface.

One should mention that a quantization of the gravitational field, which appears to be necessary for physical reasons, may be carried out without any new difficulties by means of a formalism wholly analogous to that applied here. **(Heisenberg and Pauli 1929, p. 3)**

Quantum theory + theory of the electromagnetic field + theory of gravitation → **Cosmological theory**



**Quantized**

Quantum Mechanics → Information based physics → Quantum gravity

**Relativistic**

General Relativity → Information based physics → Quantum gravity

**Kinetic theory** → explains the behavior of gases

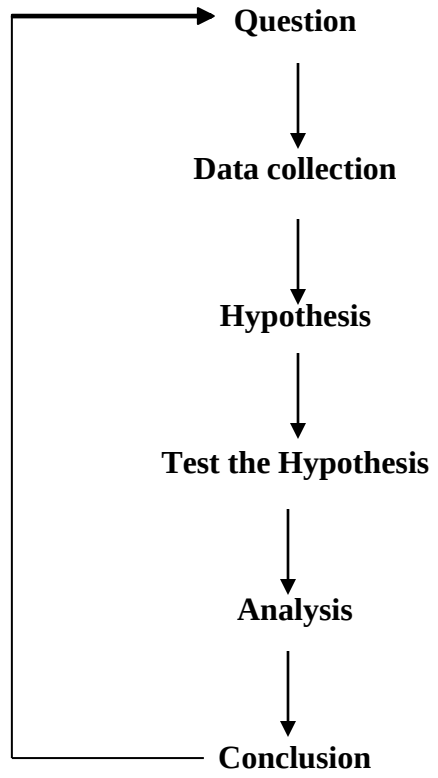
**Maxwell's theory of electromagnetism** → explains the phenomena of electricityand magnetism

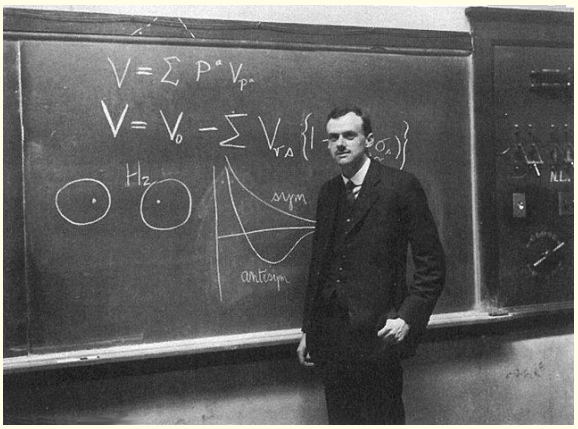
Predicted electromagnetic waves

| | | | | |
|---|---|---|---|---|
| $\Omega < 1$ | $k = -1$ | $<180^o$ | Hyperbolic (Negative space curvature) | Open Universe |
| $\Omega = 1$ | $k = 0$ | $180^o$ | Flat (Euclidean) | Critical universe |
| $\Omega > 1$ | $k = +1$ | $>180^o$ | Spherical (Positive space curvature) | Close Universe |

$k$ → curvature of the universe

## The Scientific Method: 6 Steps for Investigating Our World



P.A.M. Dirac at the blackboard

$\frac{a_2}{a_1}$ = Expansion magnification factor

- $a_2$ → Scale factor of the universe at time $t_2$
- $a_1$ → Scale factor of the universe at time $t_1$

**The biggest black hole in the cosmos is 66 billion times more massive than the Sun.**

**Pluto's atmosphere is incredibly thin because it is so cold that nitrogen freezes into solid form.**

- The CMB displays temperature fluctuations of order $\frac{\Delta T}{T} \sim 10^{-5}$ on scales of order one degree.

The **radioactive displacement law**, also known as the **Fajans-Soddy law**, was developed independently by **Kasimir Fajans** and **Frederick Soddy** in the early 20th century. It states that in radioactive decay, alpha particles are emitted from the nucleus of the parent atom, causing the atomic number of the daughter atom to decrease by 2, while the mass number decreases by 4. In contrast, beta particles are emitted from the nucleus and do not affect the mass number but increase the atomic number by 1, as a neutron is transformed into a proton. **Therefore, the law can be summarized as follows:**

- **In alpha decay, the daughter atom has an atomic number 2 less and a mass number 4 less than the parent atom.**
- **In beta decay, the daughter atom has an atomic number 1 more than the parent atom, but the same mass number.**

The **Fajans-Soddy law** is a fundamental principle in nuclear physics and is used to understand the different types of radioactive decay and their effects on the nucleus of an atom.



**Kazimierz Fajans**



**Frederick Soddy**

$L_\odot = 4 \times 10^{33}$ erg / s = solar luminosity.

Known stars have luminosity in the range $10^{-5} - 10^{6}\ L_\odot$.

$M_{bol} = 4.8 - 2.5 \log\left(\frac{L}{L_\odot}\right)$ = absolute bolometric magnitude of a star with a luminosity L

$M_V = M_{bol} - BC$ = absolute visual magnitude of a star

BC is a bolometric correction

| | | |
|---|---|---|
| $\rho \propto \frac{1}{a^3}$ | $P = 0$ | matter |
| $\rho \propto \frac{1}{a^4}$ | $P = \frac{\rho}{3}$ | radiation |
| $\rho \propto a^0$ | $P = -\rho$ | vacuum |

✓ **As the universe expands:**

- Photon frequencies redshift with

$$\upsilon \propto \frac{1}{a}$$

and a blackbody curve will be preserved with temperature

$$T \propto \frac{1}{a}$$

✓ **Each of the fundamental forces has an energy scale associated with it.**

$E = k_B T_{\text{freeze out}}$

$T_{\text{freeze out}}$ → Temperature above which that fundamental force freezes out

| | Temperature (K) |
|---|---|
| strong forces freeze out | $> 10^{27}$ |
| weak forces freeze out | $> 10^{15}$ |

| Law | Model |
|---|---|
| Exact | Approximate |
| Applies to everything | Applies to some things only |

**Law of energy conservation**

**Bohr model of the atom**

"[Statistical thermodynamics] is the only physical theory of universal content, which I am convinced, that within the framework of applicability of its basic concepts will never be overthrown."

**−Albert Einstein**

"If we wish to find in rational mechanics an a priori foundation for the principles of thermodynamics, we must seek mechanical definitions of temperature and entropy."

**—J. Willard Gibbs**

"Available energy is the main object at stake in the struggle for existence and the evolution of the world."

**—Ludwig Boltzmann**


Ludwig Boltzmann
geboren in Wien 1844.
N. Stockmann
WIEN
IX Währingerstr. 18.

✔ **Ludwig Boltzmann** was an Austrian physicist and one of the pioneers of statistical mechanics. His work on the **statistical interpretation** of **thermodynamics** was groundbreaking and laid the foundation for the modern understanding of entropy. **Boltzmann's contributions** to the field were not recognized during his lifetime, and he struggled with mental health issues. This tragic aspect of his life and the broader issue of the treatment of innovators in science have been topics of much discussion and analysis. **Boltzmann's work** on **statistical mechanics** was crucial in explaining the **behavior of gases** and the concept of **entropy**. He showed that the behavior of a gas could be understood by considering the random motion of its constituent particles. This work led to the formulation of the famous **Boltzmann distribution**, which describes:

$$P \propto e^{-\frac{E_i}{k_B T}}$$

where P represents the probability of a particle occupying a specific energy state " i ", $\mathbf{E_i}$ is the energy of the state " **i** ", $k_B$ is Boltzmann's constant and T is the temperature of the system in Kelvin.

**Boltzmann's work on entropy** also provided a theoretical explanation for the **second law of thermodynamics**, which states that the **total entropy of an isolated system tends to increase over time or remain constant but never decreases**.

$$\Delta S \geq 0$$

Despite his groundbreaking contributions to the field, **Boltzmann's work** was not always appreciated during his lifetime. He faced opposition from some of his contemporaries who were wedded to the old ways of thinking about **thermodynamics**. In particular, the **French physicist**



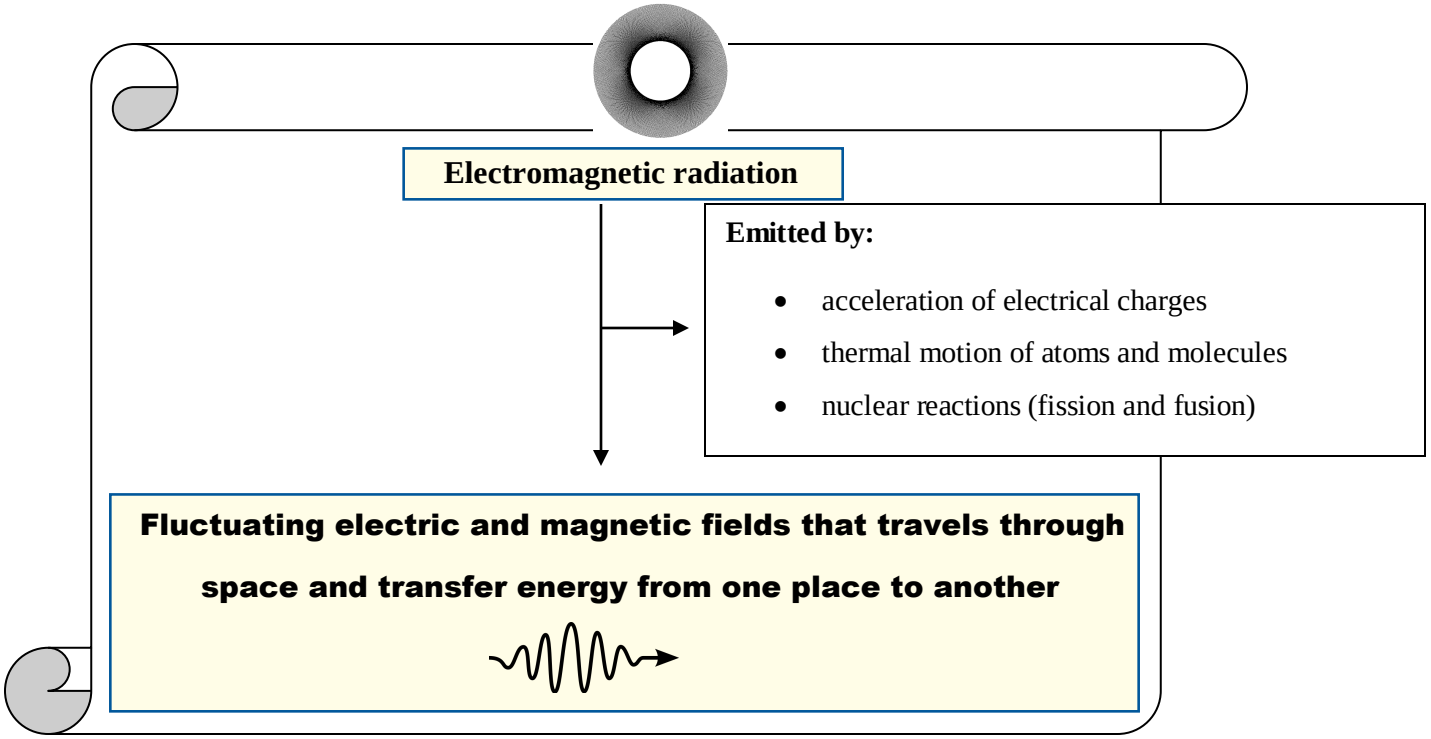
**Henri Poincaré** was a vocal critic of Boltzmann's ideas. **Poincaré** argued that **Boltzmann's statistical interpretation of entropy** was not fundamental and that the second law of thermodynamics was based on deeper principles.

**Boltzmann** and **Poincaré** engaged in a bitter debate over these issues that lasted for years. **Boltzmann's struggles** were not limited to the intellectual sphere. He also faced personal and emotional challenges. He suffered from **depression and anxiety** throughout his life and was deeply affected by the deaths of his father and brother. **Boltzmann's mental health issues** were exacerbated by the stresses of his professional life, including the opposition he faced from his peers. In 1906, **Boltzmann** took his own life while on vacation in Italy. He was just **62 years old**. The **tragedy of Boltzmann's life** has led to much discussion about the treatment of innovators in science. Many have argued that **Boltzmann's work** was not fully appreciated during his lifetime because he was ahead of his time. Others have suggested that his **mental health issues** were exacerbated by the pressures of academic life and the lack of recognition for his contributions. The debate over the **treatment of innovators** in science continues to this day. Overall, **Ludwig Boltzmann** was a brilliant physicist who made groundbreaking contributions to the field of **statistical mechanics**. His work on the **statistical interpretation of thermodynamics** was fundamental in the development of modern physics. However, his contributions were not always appreciated during his lifetime, and he faced significant opposition from some of his contemporaries. Throughout his life, **Boltzmann** also battled mental health problems, and at the age of 62, he committed **suicide**. The tragic death of Boltzmann has sparked significant debate about how scientists should be treated as innovators and the importance of encouraging and honouring individuals who are pushing the boundaries of knowledge.

## Inflatable space habitat

A type of structure designed to provide living and working environment for astronauts in space and have the advantage of being lightweight and compact during transportation to space. They can be compressed and folded into a compact form for launch and then expanded and pressurized once they are deployed in space.

| | |
|---|---|
| **dark energy** | The energy of empty space that drives the acceleration of the expanding universe |
| **dark matter** | Nonluminous matter that is detected only by its gravitational influence |
| **degenerate matter** | Extremely high-density matter in which pressure no longer depends on temperature |




| | |
|---|---|
| **extremophile** | An organism that can survive in an extreme environment |
| **free-fall collapse** | The early contraction of a gas cloud to form a star during which internal pressure is too low to resist contraction |
| **geocentric universe** | A model universe with Earth at the center |

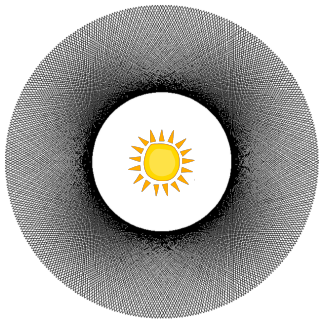
bound → unbound **(ionization)**
unbound → bound **(recombination)**

**Transmissivity (τ) + Reflectivity (α) + Absorptivity (ξ) = 1**

All objects above absolute zero (−273.15 °C) emit **Electromagnetic radiation**

- Reflection
- Scattering
- Refraction
- Absorption

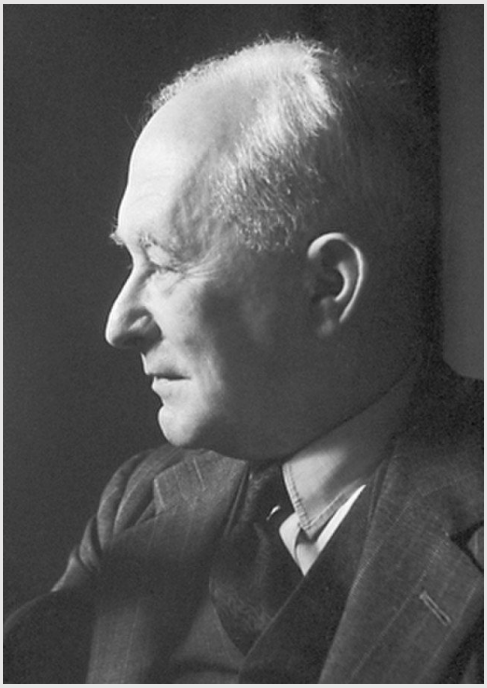
**Processes that occur in the atmosphere**



- **Albedo** is a measure of how much light that hits a surface is reflected without being absorbed

**The more massive a star is, the more luminous it is.**

| | |
|---|---|
| **helioseismology** | The study of the interior of the sun by the analysis of its modes of vibration |
| **Hertzsprung–Russell (H–R) diagram** | A plot of the intrinsic brightness versus the surface temperature of stars |
| **interstellar extinction** | The dimming of starlight by gas and dust in the interstellar medium |
| **iron meteorite** | A meteorite composed mainly of iron–nickel alloy |
| **light pollution** | The illumination of the night sky by waste light from cities and outdoor lighting – which prevents the observation of faint objects |
| **Milankovitch hypothesis** | The hypothesis that small changes in Earth's orbital and rotational motions cause the ice ages. |
| **millisecond pulsar** | A pulsar with a period of approximately a millisecond − a thousandth of a second |
| **monolithic collapse hypothesis** | The hypothesis that the Milky Way Galaxy formed by gravitational collapse of a single large spinning cloud of gas |
| **nucleosynthesis** | The production of elements heavier than helium by the fusion of atomic nuclei in stars and during supernovae explosions |
| **opacity** | The resistance of a gas to the passage of radiation |

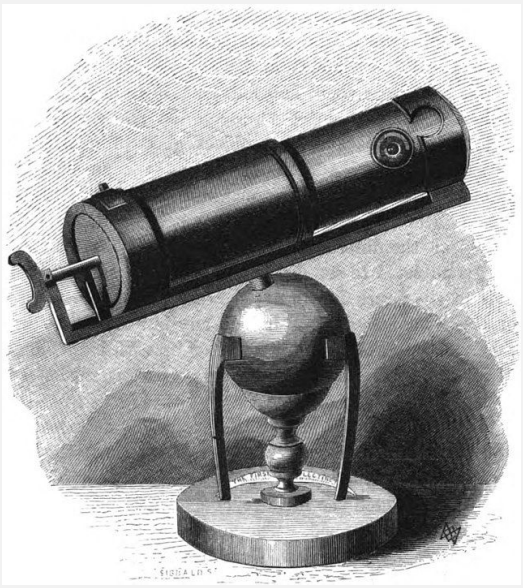


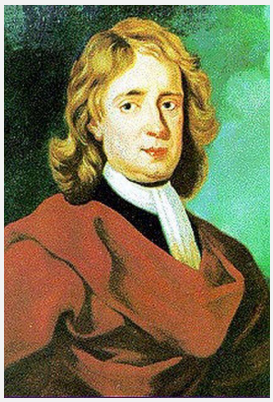
"Science is not formal logic–it needs the free play of the mind in as great a degree as any other creative art. It is true that this is a gift which can hardly be taught, but its growth can be encouraged in those who already posses it."

– Max Born

# From Göttingen to the Nobel: The Remarkable Journey of Wolfgang Pauli

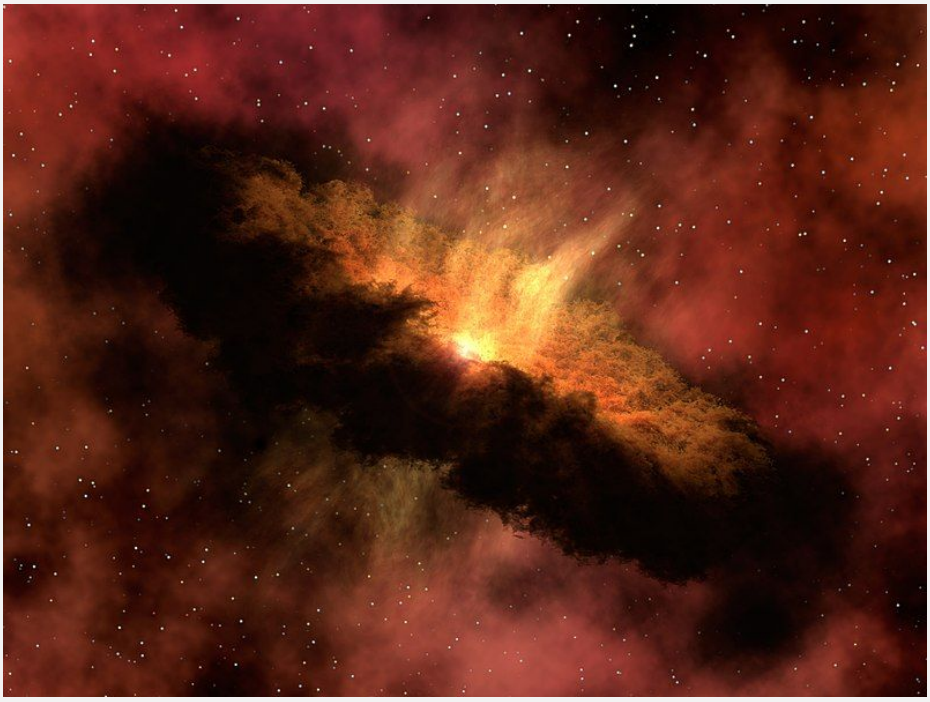
**Wolfgang Pauli** was a pioneering physicist whose contributions to **quantum mechanics** have had a lasting impact on the field of physics. He was born in **Vienna**, Austria, in 1900, and his early interest in science was fostered by his father, a well-known chemist. **Pauli** began his studies in physics at the **University of Munich** in 1918, and later continued his education at the **University of Göttingen**, where he worked under the guidance of physicist **Max Born**. It was during this time that Pauli began to develop his ideas about **quantum mechanics**. One of Pauli's most important contributions to physics was the formulation of the **"Pauli exclusion principle,"** which states that **no two identical fermions can occupy the same quantum state simultaneously**. This principle has important implications for the behavior of electrons in atoms and the properties of metals, and has been verified through numerous experiments. **Pauli's work on beta decay**, the emission of electrons or positrons from atomic nuclei, also earned him recognition in the field of physics. He was able to explain the seemingly paradoxical results of experiments on **beta decay** by proposing the existence of a new particle, **the neutrino**. This particle, which had been previously hypothesized by **physicist Enrico Fermi**, was eventually detected by scientists in the 1950s. **Pauli** was also known for his contributions to the **"Copenhagen interpretation"** of quantum mechanics, which emphasizes the probabilistic nature of quantum phenomena. This interpretation, which was developed by a group of physicists including **Niels Bohr** and **Werner Heisenberg**, had a significant impact on the development of quantum mechanics as a field. Beyond his scientific work, **Pauli** was also known for his interest in **philosophy**, **psychology**, and the **history of science**. He was a prolific writer, and his correspondence with other physicists of the time has been collected and published in a multi-volume set. Despite his many accomplishments, **Pauli** was a **respected and influential member** of the **scientific community**, and he mentored many young physicists who went on to become leaders in the field. **Pauli** was awarded the **Nobel Prize in Physics** in 1945 for his work on the exclusion principle and his contributions to the development of quantum mechanics. He continued to work and publish in the **field of physics** until his death in 1958, at the age of 58. Today, he is remembered as **one of the most important physicists** of the 20th century, and his ideas continue to inspire new discoveries and innovations in the field of physics.



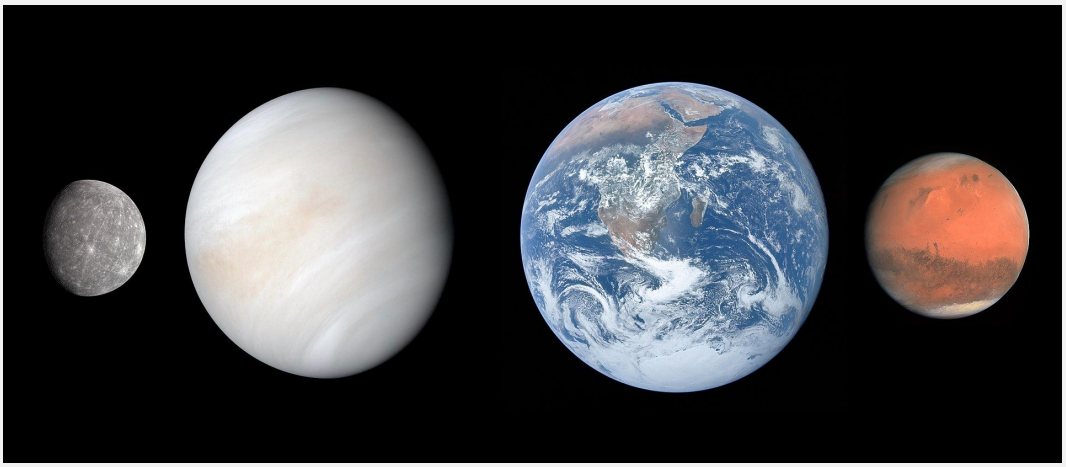




**The first reflecting telescope, built by British physicist Isaac Newton in 1668.**

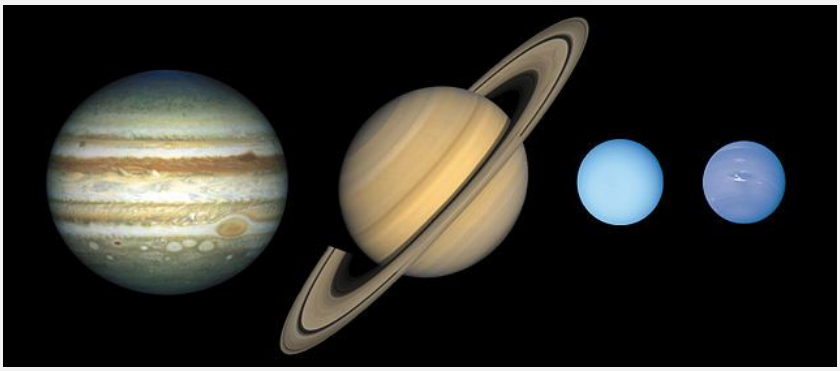


**A depiction of the protoplanetary disc, which gave rise to Earth and other Solar System bodies, in the early Solar System.**



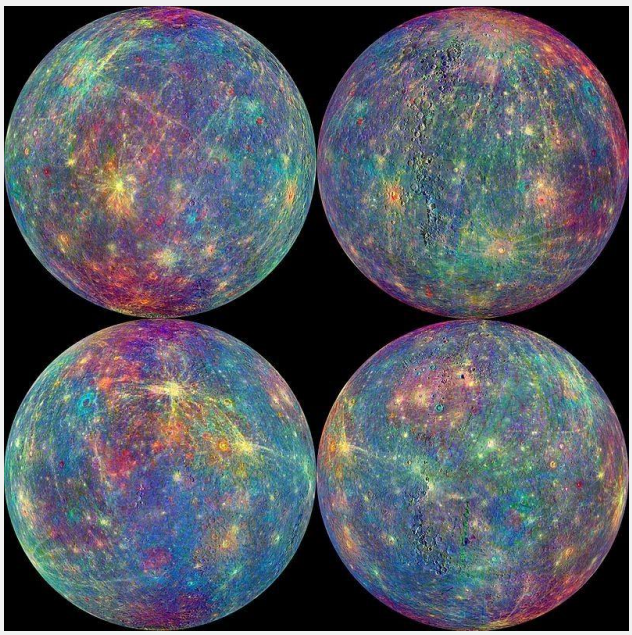
**The four terrestrial planets: Mercury, Venus, Earth and Mars**

The four terrestrial planets are the inner planets of our solar system, which are also known as the rocky or solid planets, as they are primarily composed of rock and metal. These planets are relatively small in size and have dense, rocky surfaces with few or no moons. They also have solid cores, and their atmospheres are thin and composed mainly of carbon dioxide, nitrogen, and other trace gases.

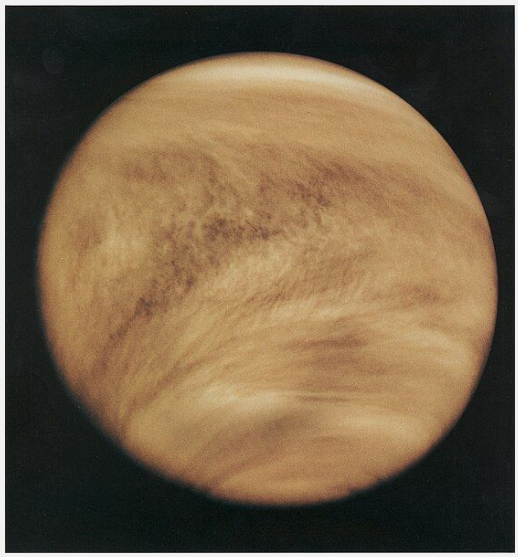


**The four gas giants: Jupiter, Saturn, Uranus, and Neptune**

The four gas giants, also known as the Jovian planets, are the outer planets of our solar system. Unlike the terrestrial planets, the gas giants are much larger in size and are composed mostly of gas and liquid, with no solid surface. They have thick atmospheres consisting mainly of hydrogen and helium, along with traces of methane, ammonia, and other gases. The gas giants also have numerous moons and ring systems, and they all have strong magnetic fields.



**Mercury Atmospheric and Surface Composition Spectrometer spectrum** scan of Mercury's surface by **ME**rcury **S**urface, **S**pace **EN**vironment, **GE**ochemistry, and **R**anging (MESSENGER) spacecraft.



**Ultraviolet image** of **Venus' clouds** as seen by the **Pioneer Venus Orbiter** (February 26, 1979)

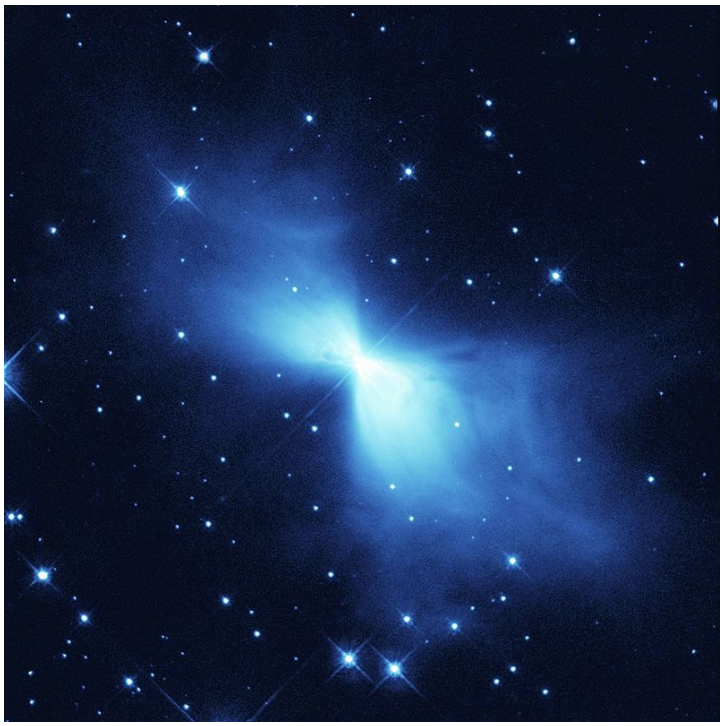
☀The second planet from the Sun, **Venus**, takes 224.7 Earth days to complete one orbit around the Sun.



- ✓ **Absolute zero:** The lowest possible temperature that can theoretically be reached in the universe at which all molecular and atomic motion theoretically ceases, and substances contain no heat energy. It is equivalent to **– 273.15 degrees Celsius** or **– 459.67 degrees Fahrenheit**. The **third law of thermodynamics** states that as the temperature approaches **absolute zero**, the entropy of a perfectly crystalline substance also approaches zero. This law implies that at **absolute zero**, a perfectly crystalline substance would have **no disorder or randomness** in its atomic or molecular arrangement, resulting in **zero entropy**. However, it's important to note that achieving **absolute zero** is not practically possible, and thus, the **absolute zero** serves as a theoretical concept rather than an achievable state. In the framework of **quantum mechanics**, **absolute zero** refers to the lowest possible temperature where matter **(solid)** reaches its ground state, which corresponds to the state of lowest internal energy.



**Robert Boyle** is credited with pioneering the idea of **absolute zero**.



With a temperature of 1 K, the rapidly expanding gases leaving the **Boomerang Nebula** in **Centaurus**, a bi-polar, filamentary, and possibly **proto-planetary nebula**, presents the coldest temperature **ever observed** outside of laboratory conditions.

✓ **Acceleration:** The rate at which the velocity of an object is changing with respect to time and it is given by the equation: $a = \frac{dv}{dt} = \frac{d(\frac{dx}{dt})}{dt} = \frac{d^2x}{dt^2}$. In **non-relativistic mechanics**, which is the classical framework of mechanics that does not consider relativistic effects, the **acceleration** of a body with **constant mass** is proportional to the **net force** acting on it:

$$a \propto F \text{ or } a = \frac{F}{m}$$

The greater the force acting on an object or the smaller its mass, the larger its resulting acceleration will be.

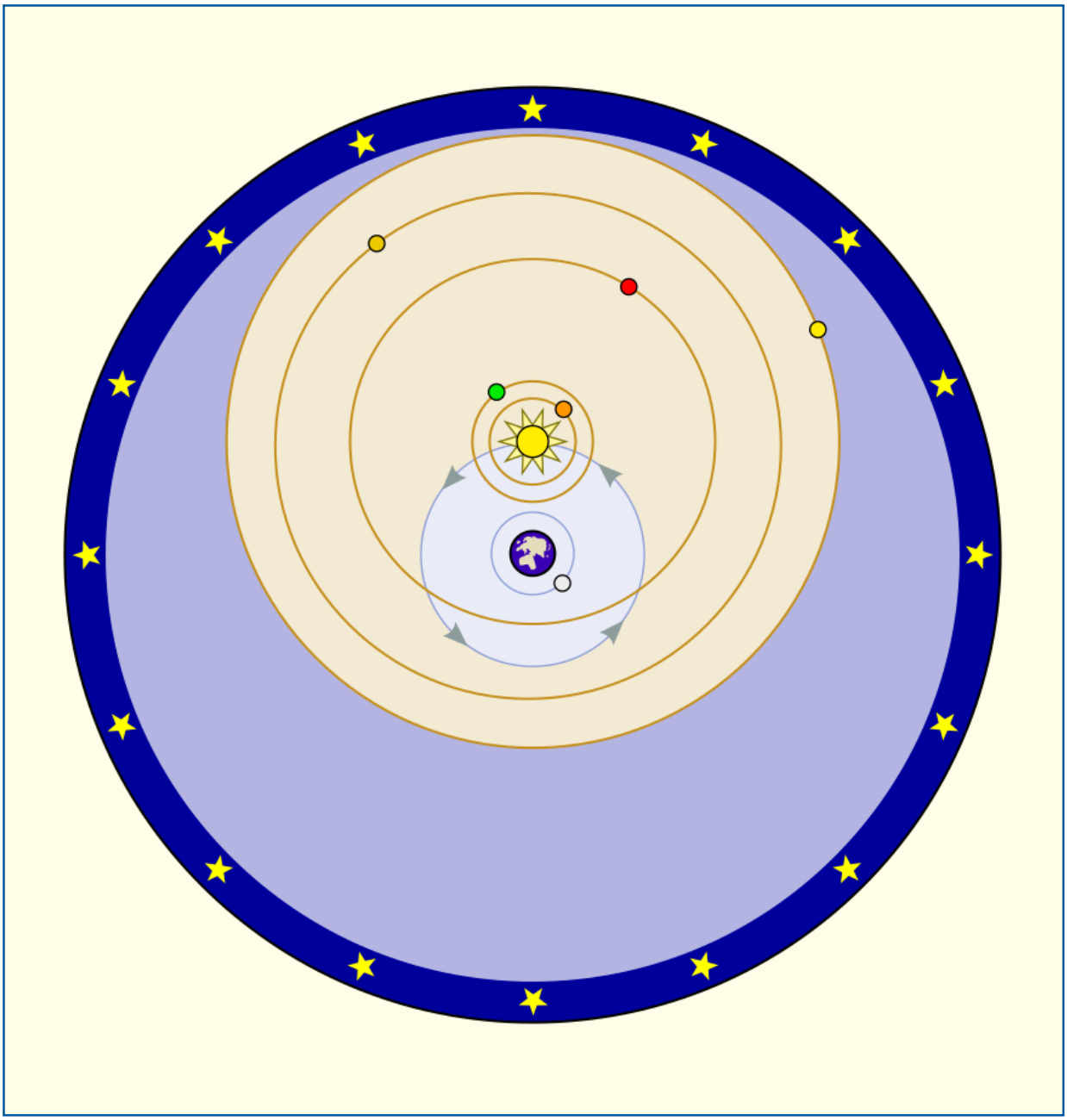
In circular motion, the **centripetal acceleration** ($a_c$) of a particle is inversely proportional to the **radius of the circular path** (r) and increases as the **square of the speed** (v) of a particle:

$$a_c = \frac{v^2}{r} = \omega^2 r$$

ω is the angular speed of a particle.

**This means that:**

- Particle moving in smaller circlar path experience higher centripetal acceleration.
- As the speed of the particle increases, the centripetal acceleration increases at a greater rate.



**In the Tychonic cosmological model,** the **Earth** is stationary at the center of the universe, while the **Moon,** the **stars,** and the **Sun** revolve around the **Earth**. The five planets, however, are considered to revolve around the **Sun**, as proposed by Copernicus.




**Monument of Tycho Brahe and Johannes Kepler in Prague, Czechia**

- ✓ **Anthropic principle:** We see the universe the way it is because if it were different we would not be here to observe it through a gigantic telescopes pointing deep into the immense sky – merely stating that the **constants of nature** must be tuned to allow for intelligence (otherwise we would not be here). Some believe that this is the sign of a **cosmic creator**. Others believe that this is a sign of the **multiverse**.

- ✓ **Antiparticle:** Each type of matter particle has a corresponding antiparticle – first predicted to exist by **P. A. M. Dirac**. When a particle collides with its antiparticle, they annihilate, leaving only pure energy in the form of discrete bundle **(or quantum)** of electromagnetic **(or light)** energy called **photons**. The **electric charge** is one of the most well-known properties that differs between particles and antiparticles. **For example**, an **electron**, which carries a **negative charge**, has an antiparticle called the **positron**, which carries a **positive charge**. Similarly, a **proton**, which carries a **positive charge**, has an antiparticle called the **antiproton**, which carries a negative charge.

**An atom of hydrogen:**

Atom in which the nucleus is a proton with an orbiting electron.

**An atom of antihydrogen:**

Atom in which the nucleus is an antiproton with an orbiting positron.

- ✓ **Atom:** The **basic unit** of ordinary matter, made up of a **tiny nucleus** (consisting of positively charged **protons** and electrically neutral **neutrons** – which obey the strong interactions) surrounded by orbiting negatively charged particles called the **electrons**.

- ✓ **Big Bang:** A scientific theory that describes the **origin** and **early development** of the universe. According to this theory, the universe began as an extremely **hot** and **dense state** approximately **13.8 billion years ago**. It postulates that all matter, energy, space, and time originated from a singular point of **infinite density** and **temperature** known as a **singularity**. One of the key pieces of evidence supporting the **Big Bang theory** is the discovery of the **cosmic microwave background radiation**. It is the remnant **heat radiation** from the early universe, which has cooled over time and is now detected as **microwave radiation** uniformly spread throughout space.While the **Big Bang theory** is widely accepted among scientists, there are still many unanswered questions about the precise **nature of the singularity** and what occurred in the earliest moments of the universe. Ongoing research and observations continue to refine our understanding of the **Big Bang** and the **evolution of the universe**.

- ✓ **Big crunch:** A hypothetical scenario in cosmology where the density of matter and energy in the universe is high enough, the **gravitational forces** would eventually overpower the **ongoing expansion**. Consequently, the **cosmic expansion would reverse**, causing all matter and energy to become progressively compressed. This compression would continue until reaching an **extreme state** of density and temperature, ultimately resulting in a cosmic collapse and the formation of a **singularity**.

- ✓ **Big freeze:** The **Big Freeze**, also known as the **Heat Death of the Universe**, is a theoretical scenario in cosmology describing the ultimate fate of the universe. According to this scenario, the universe will continue expanding and cooling down until it reaches a state of maximum entropy. All energy sources will be depleted, and the universe will become a cold and desolate place, unable to sustain life or any significant processes.

- ✓ **Big Bang nucleosynthesis:** The process that occurred in the early stages of the universe, shortly after the **Big Bang**, during which the **primordial elements** were

formed. It was facilitated by the high temperatures and densities of the early universe, allowing for the **fusion** of protons and neutrons to create **elements** such as hydrogen, helium-4, deuterium, helium-3, and trace amounts of lithium-7. **Big Bang nucleosynthesis** laid the foundation for the subsequent evolution of the universe, providing the initial abundances of light elements that would later contribute to the formation of stars, galaxies, and the complex structures we observe today.

When the Universe was a few seconds old, at high temperature, the universe consisted of photons, electrons, positrons, neutrinos and their antiparticles. There was also a small number of protons and neutrons. The neutrons and protons were continuously converted into each other in processes such as:

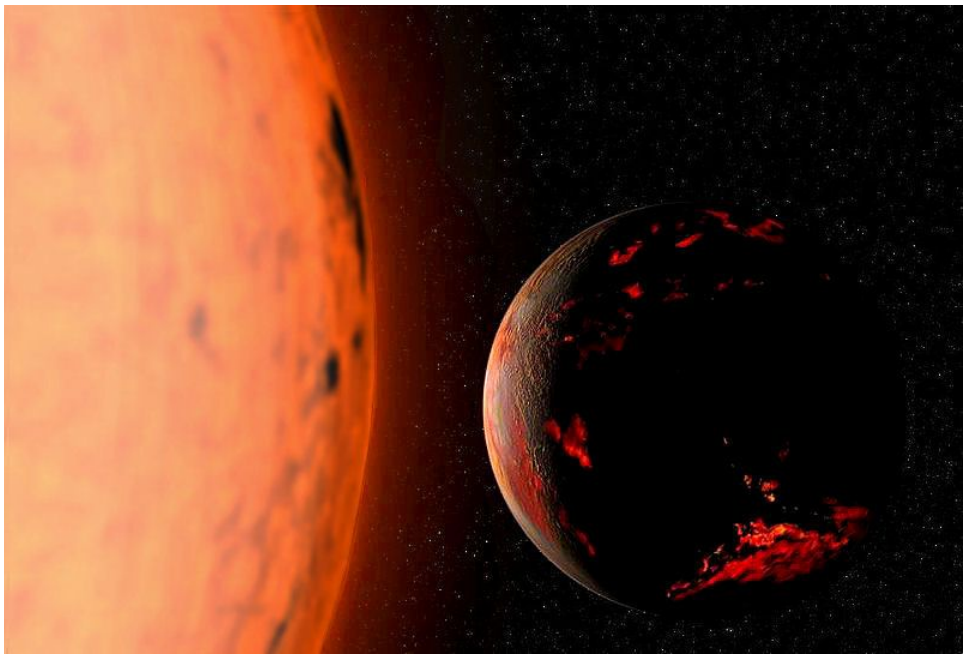
**neutron → proton + electron + antineutrino**.

In this process, a **neutron** with a **decay time of 890 seconds** spontaneously decayed into a proton while emitting an electron **(also called a beta particle)** and an antineutrino.

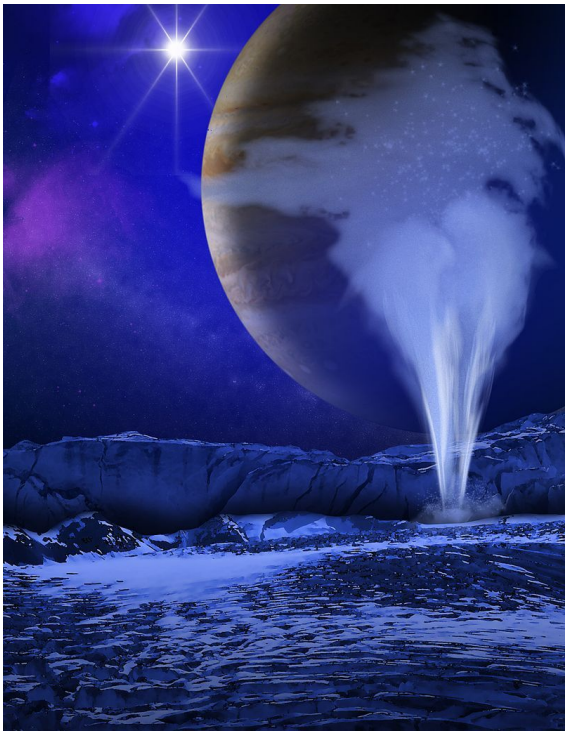
**proton + electron → neutron + neutrino**

Conversely, a proton absorbed an electron and converted into a neutron, emitting a neutrino in the process. **Protons** and **neutrons** were in thermal equilibrium, and $\frac{\text{number of neutrons}}{\text{number of protons}} \propto e^{-\frac{(m_n - m_p)c^2}{k_B T}}$. As $(m_n - m_p)\, c^2 = 1.29\text{MeV}$, this implied a corresponding value of $k_B T \approx 1.5 \times 10^{10}$ K. Electrons and positrons were also in thermal equilibrium at this epoch, i.e.

**gamma photon + gamma photon ↔ positron + electron**



**Artistic conception of the distant future**, approximately 5 to 7.5 billion years from now, the Sun will undergo significant changes and transform into a **red giant**. During this phase, the Sun will exhaust its core hydrogen fuel, causing it to expand and become much larger in size compared to its current state.



This image portrays an artistic interpretation of a plume of water vapor believed to be expelled from the icy, cold surface of Europa, one of Jupiter's moons. Europa is located approximately 500 million miles (800 million kilometers) away from the Sun.

## Black hole:

A **black hole** is a region of spacetime exhibiting gravitational acceleration so strong that nothing—no particles or even electromagnetic radiation such as light—can escape from it. A sufficiently compact mass can distort spacetime to create a **black hole**, according to **Albert Einstein's general relativity theory**. Four different types of black holes are recognized: stellar, intermediate, supermassive, and small. **Stellar black holes** are formed from the collapse of massive stars, have masses ranging from about 5 to 30 times that of the sun, and are usually found in binary systems. **Intermediate black holes** are thought to have masses of a few thousand to a million times that of the sun and may be the missing link between stellar and supermassive black holes. **Supermassive black holes** have masses of millions to billions of times that of the sun and are found at the centers of most galaxies, including the **Milky Way**. **Small black holes** are hypothetical with masses less than a few times that of the sun and have not yet been observed. **Black holes** are invisible, but their presence can be inferred by observing their effects on nearby matter.

## Black Hole Escape Velocity:

The escape velocity of a black hole is the minimum speed an object must have in order to escape the gravitational pull and not fall back into the black hole. For a black hole, the escape velocity is equal to the speed of light, meaning that nothing, including light, can escape from the black hole once it crosses the event horizon. This property is what makes black holes "black," as no light or radiation can be seen from outside the event horizon. The escape velocity at the surface of an astrophysical object is directly proportional to its mass, meaning that the more massive the object, the higher the escape velocity and the stronger is its gravitational pull.

The study of **quantum black holes** is a highly active area of research, as it seeks to understand the behavior of black holes at the quantum level and to reconcile the seemingly conflicting theories of general relativity (which describes the behavior of black holes) and quantum mechanics. While progress is being made, a complete **theory of quantum black holes** is still not fully understood and remains a topic of ongoing research.

The **"cosmic censorship conjecture"** is a hypothesis in theoretical physics that states that the singularities inside black holes are always hidden behind an event horizon, and hence, cannot be observed by external observers. In the context of the **cosmic censorship conjecture**, the total electric charge **Q** and the total angular momentum **J** of a black hole are expected to satisfy the following inequality:

$$\frac{Q^2}{4\pi\varepsilon_0} + \frac{c^2 J^2}{GM^2} \leq GM^2$$

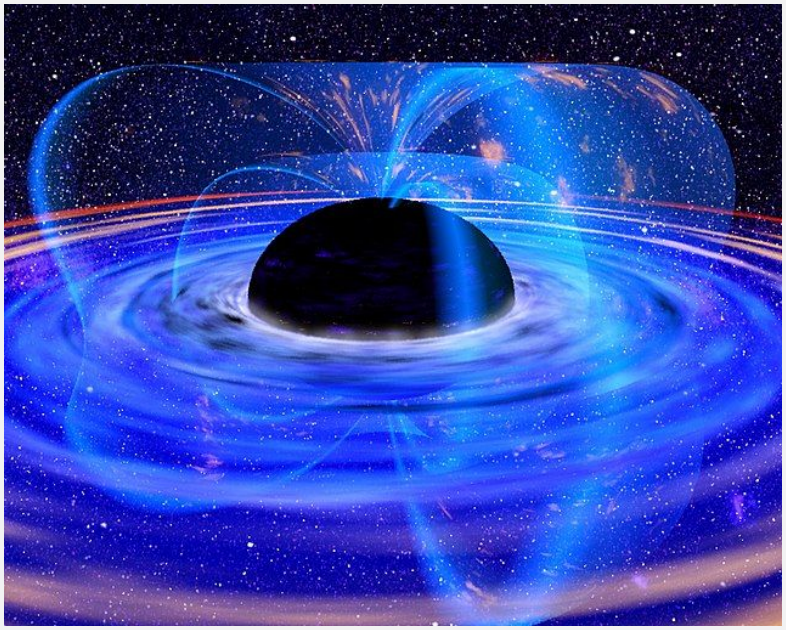
where c is the speed of light, G is the gravitational constant, and $\varepsilon_0$ is the permittivity of free space. This inequality implies that a black hole cannot have too much charge or too much angular momentum relative to its mass. If it did, it would violate the **cosmic censorship conjecture** by allowing its singularity to be visible to external observers, which is thought to be impossible according to **general relativity**.

For uncharged rotating black hole:

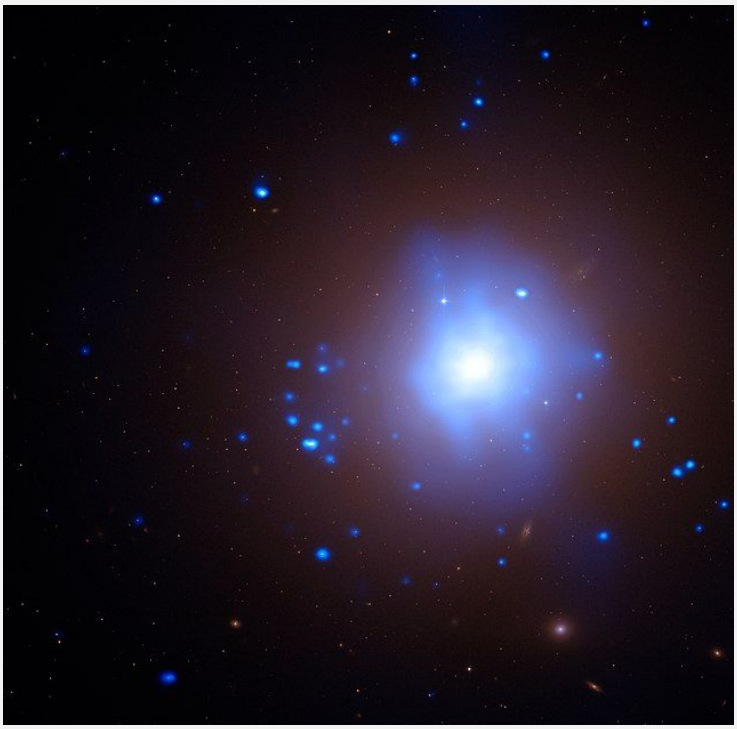
$$Q = 0$$

$$J \leq \frac{GM^2}{c}$$

This inequality implies that there is a maximum amount of angular momentum that a black hole can possess for a given mass. If the black hole were to exceed this limit, it would become unstable and eventually break apart.



**An artist's impression of a black hole accretion disk**



**Massive Black Hole Implicated in Stellar Destruction**



**The supermassive black hole at the centre of this distant galaxy is depicted in this artist's conception as it consumes the remains of a star.**

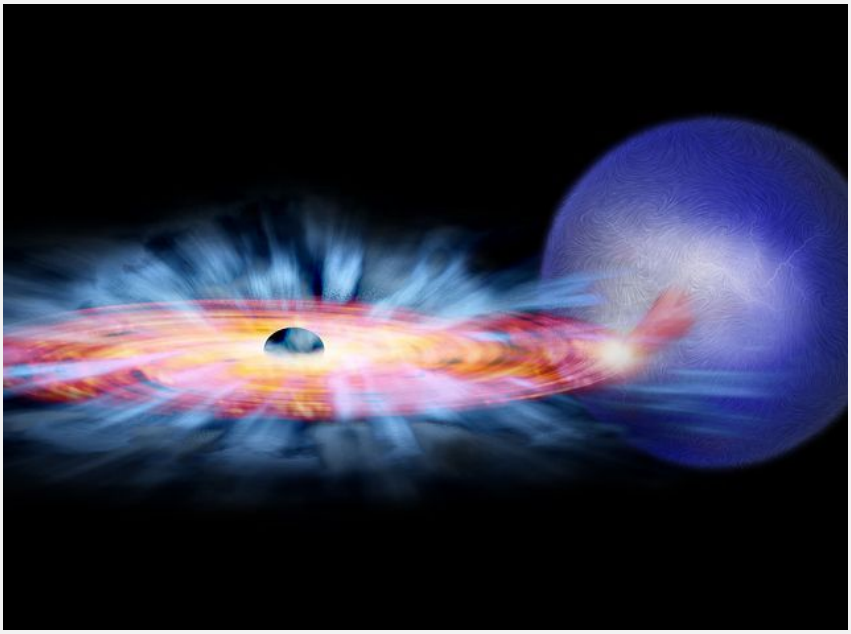
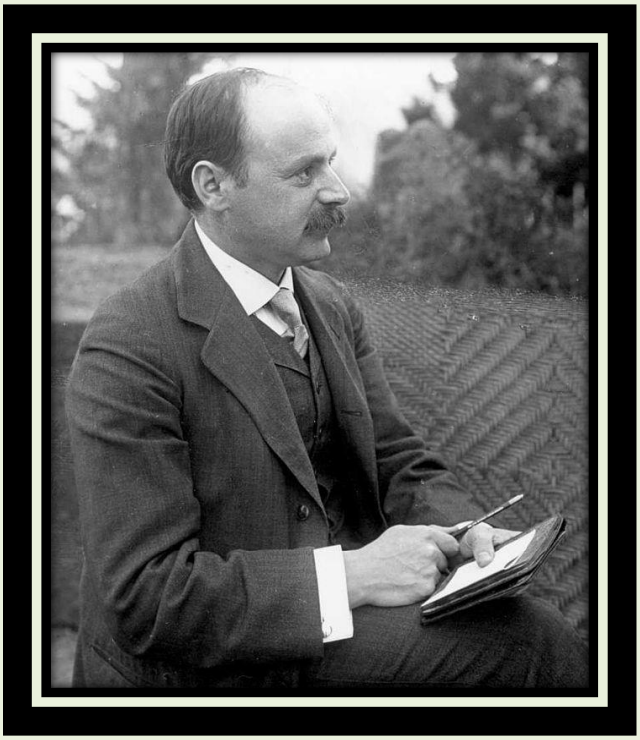


**Illustration of a Stellar-Mass Black Hole**

## Schwarzschild Black Hole

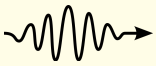
A **Schwarzschild Black Hole** is a non-rotating and uncharged black hole, described by the famous German physicist **Karl Schwarzschild** in 1916. It is characterized by a singularity at the center, surrounded by an event horizon, beyond which nothing can escape its gravitational pull. The size of the event horizon, also known as the **Schwarzschild radius**, depends on the mass of the black hole. The equations describing the structure of a Schwarzschild black hole form the basis for our understanding of black holes in general.



**Karl Schwarzschild**

A **Kerr black hole** is a rotating black hole that was first described by the New Zealand mathematician **Roy Patrick Kerr** in 1963. It is characterized by a central singularity surrounded by an event horizon, and by a region known as the **ergosphere**, within which any object must rotate with the black hole. The size of the event horizon and the structure of the black hole are described by the **Kerr metric**, which is a solution to the **Einstein field equations of general relativity**. Unlike a **Schwarzschild black hole**, which is non-rotating, a **Kerr black hole** has angular momentum and is therefore described as a **"rotating"** black hole.

## Kerr-Newman black hole



A **Kerr-Newman black hole** is a charged, rotating black hole that was first described by the physicists **Roy Kerr**, **Ezra Newman**, and **Ted Jacobson** in 1965. It is characterized by a central singularity surrounded by an event horizon, and by a region known as the **ergosphere**, within which any object must rotate with the black hole. The size of the event horizon, the structure of the black hole, and the distribution of the electric charge are described by the **Kerr-Newman metric**, which is a solution to the Einstein-Maxwell field equations of general relativity and electromagnetism. A **Kerr-Newman black hole** is the most general and complete description of a black hole, incorporating both angular momentum and electric charge.

## Reissner-Nordstrom solution

The **Reissner-Nordstrom solution** is a solution to the **Einstein-Maxwell field equations** of general relativity and electromagnetism that describes a charged, non-rotating black hole. It was first described by the physicists **Hans Reissner** and **Gunnar Nordström** in 1916. The **Reissner-Nordstrom solution** is a special case of the more general **Kerr-Newman solution**, which describes a charged, rotating black hole.

The **Cauchy horizon** is often associated with a breakdown of determinism in the context of black holes. The presence of a **Cauchy horizon**, a boundary within a black hole, implies that the **laws of physics**, as we currently understand them, fail to predict events beyond that point. As for the claim made by physicists, including **Roger Penrose**, that no observer could pass through the **Cauchy horizon** without being annihilated. If an observer were to cross the **Cauchy horizon** and access the region beyond it, they would potentially encounter the **singularity** and experience extreme **gravitational forces**, **tidal forces**, and other unknown physical effects. The conjecture is that these forces would be so powerful that they would lead to the observer's destruction or annihilation, preventing them from transmitting any information or signals back to the external universe.

**The first law of black hole thermodynamics:**

$$dE = \frac{k dA}{8\pi} + \Omega dJ + \phi\, dQ$$

where E is the energy, $k$ is the surface gravity, A is the horizon area, $\Omega$ is the angular velocity, J is the angular momentum, $\phi$ is the electrostatic potential and Q is the electric charge.

- For **Reissner–Nordström black holes**, the first law reads:

$$dE = \frac{k dA}{8\pi} + \phi\, dQ$$

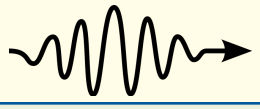
- For **Kerr black holes**, the first law reads:

$$dE = \frac{k dA}{8\pi} + \Omega dJ$$

- For **Schwarzschild black holes**, the first law reads:

$$dE = \frac{k dA}{8\pi}$$

**Ultracold atom**



**Atom** that has been cooled to very low temperature, near **absolute zero**. At this temperature, the **atoms' quantum-mechanical properties** become important, meaning that it behaves in ways that are not predicted by classical physics.

- ✓ **Zero point Energy (ZPE):** A fundamental and necessary component of quantum mechanics. It is the **lowest possible energy** that a **quantum mechanical system** can have. This means that even in a vacuum, where there are no particles, there is still energy present. Since the 1920s, when **quantum mechanics** was discovered, the **ZPE** has been explored both theoretically and experimentally, and there is no question that it is a real physical phenomenon. The **ZPE** has a number of potential applications. **For example,** it could be used to create new types of lasers and sensors. It could also be used to develop new ways of generating and storing energy. However, the full potential of the **ZPE** is still not fully understood.

- ✓ **Casimir effect:** This effect is indeed a real and measurable phenomenon in quantum physics. It refers to the attractive force experienced between two uncharged, parallel conducting plates placed very close to each other in a vacuum, and it was initially proposed by Dutch physicist **Hendrik Casimir** in 1948. The attractive force between two plates is given by:

$$F = -\frac{\hbar c \pi^2 A}{240 d^4}$$

where A is the area of each plate, d is the distance between the plates, $\hbar$ is the reduced Planck's constant and c is the speed of light. The **negative sign** tells us that the force is attractive in nature. The presence of $\hbar$ indicates that the force is exceedingly small in magnitude, and it also implies that the force is inherently of quantum-mechanical origin, specifically arising from the quantum fluctuations of the electromagnetic field within the vacuum between closely placed conducting plates.

For example, two parallel conducting plates with an area of 1 $cm^2$ separated by a distance of 1 µm have an attractive force of about:

$$F = -\frac{1.054571 \times 10^{-34} Js \times 299\,792\,458 \frac{m}{s} \times (3.141592)^2 \times 1 cm^2}{240 \times (1 \times 10^{-6} m)^4}$$

$$F \approx -0.0013 \text{ N}$$

- ✓ **Chandrasekhar limit:** It is the maximum mass that a white dwarf star can have before it collapses under its own gravitational pull. It was first calculated by the Indian astrophysicist **Subrahmanyan Chandrasekhar** in 1930. The limit is approximately 1.4 times the mass of the Sun. When a white dwarf exceeds this limit, it undergoes a catastrophic event called a **Type Ia supernova**.

- ✓ **Conservation of energy:** A fundamental principle in physics that states that the total energy of a closed system remains constant over time. According to this principle, energy cannot be created or destroyed; it can only be transferred or transformed from one form to another.

- ✓ **Coordinates:** Numbers that specify the position of a point in 4 dimensional space-time.

- ✓ **Cosmological constant:** It is a mysterious form of matter or energy that acts against the gravitational attraction of matter in the universe and is often equated with dark energy. Its true nature remains unknown, but it is necessary in cosmological equations to align theory with our observations of the universe. Despite ongoing research, the exact identity of the **cosmological constant** and its relationship to **dark energy** continue to elude scientists.

- ✓ **Cosmology:** The scientific study of the origin, evolution, and structure of the universe as a whole. It seeks to understand the fundamental principles and laws governing the universe on its largest scales, including its overall structure, composition, and dynamics.

- ✓ **COBE:** The **Cosmic Background Explorer**, also known as **Explorer 66**, was a **NASA** satellite that operated from 1989 to 1993. Its primary objective was to study the **cosmic microwave background radiation** (CMBR) in order to gain insights into the early universe and the Big Bang theory.

- ✓ **Dark matter:** Invisible Matter usually found in a huge halo around galaxies, clusters, and possibly between clusters, that does not interact with light or other electromagnetic radiation, making it difficult to detect directly. Its presence is inferred from its gravitational effects on visible matter and the large-scale structure of the universe. As much as **90 percent** of the mass of the universe may be in the form of dark matter and

it makes up **23 percent** of the overall matter and energy content of the universe. According to string theory, dark matter may be made of subatomic particles, such as the neutralino, which represent higher vibrations of the superstring.

✓ **Duality:** A correspondence between apparently different theories that lead to the same physical results.

✓ **Einstein-Rosen bridge:** Also known as a **wormhole**, is a theoretical concept in physics that was first proposed by **Albert Einstein** and his collaborator **Nathan Rosen** in 1935. It is a hypothetical shortcut or tunnel that could connect two distant points in space or even different universes. However, it is important to note that the **wormhole** is purely theoretical at this point, and there is no experimental evidence to support its existence. Additionally, many challenges and open questions remain regarding the stability, traversability, and formation of a **wormhole**. The energy requirements to create and sustain a wormhole are believed to be enormous, and exotic forms of matter or negative energy would be necessary. While it is a fascinating concept in science fiction and theoretical physics, its exploration is still in the realm of speculation and active research.

- ✓ $m_{electron} \approx 9.1 \times 10^{-31}$ kg
- ✓ $m_{proton} \approx 1837\ m_{electron}$
- ✓ $m_{neutron} \approx 1839\ m_{electron}$
- ✓ $m_{muon} \approx 207\ m_{electron}$
- ✓ $m_{tau} \approx 3483\ m_{electron}$

- **Visual photometry:** The brightness of an object is estimated by comparing it to a set of standard stars of known brightness.
- **Photographic photometry:** The brightness of an object is measured using a photographic plate or film.
- **Spectrophotometry:** The brightness of an object is measured as a function of wavelength (i.e., its spectrum), providing information about the object's temperature, chemical composition, and other physical properties.

✓ **Electric charge:** A property of a particle by which it may repel (or attract) other particles that have a charge of similar (or opposite) sign.

✓ **Electromagnetic force:** The force of electricity and magnetism that arises between particles with electric charge; the second strongest of the four fundamental forces – which obeys **Maxwell's equations**.

✓ **Electron:** A negatively charged subatomic particle with negative electric charge that orbits the nucleus of an atom and determines the chemical properties of the atom.

The acceleration experienced by a non-relativistic charged particle of mass $\mathbf{m_0}$ moving with velocity **v** in the presence of an electric field **E** and magnetic field **B** is given by:

$$a = \frac{e\,(E + v \times B)}{m_0}$$

✓ **Electroweak unification energy:** The **energy** (estimated to be around 246 GeV) **above** which the distinction between the electromagnetic force and the weak force disappears.

✓ **Elementary particle:** A particle that, it is believed fundamental building block of Nature, cannot be subdivided and are not composed of other simpler particles.

✓ **Event:** Any occurrence or phenomenon that takes place at a particular location and time.

$$E = \sqrt{p^2c^2 - m_0^2c^4}$$

$$\begin{cases} m_0c^2 + \dfrac{p^2}{2m_0}, & \text{for } p << m_0c \textbf{ (non-relativistic)} \\ pc, & \text{for } p >> m_0c \textbf{ (ultra-relativistic)} \end{cases}$$

✓ **Event horizon:** A boundary that separates the inside of the black hole from the rest of the universe. It marks the point of no return beyond which nothing, not even light, can escape the gravitational pull of the black hole. Once an object passes the event horizon, its fate is sealed, and it cannot communicate with the outside world. It will be inevitably drawn into the black hole's singularity, a region of infinite density at its center.

✓ **Exclusion principle:** Also known as **Pauli's exclusion principle**, is a fundamental principle in quantum mechanics that applies to particles with half-integer spin, such as

electrons. It was formulated by the physicist **Wolfgang Pauli** in 1925. The **exclusion principle** states that no two electrons (or any other identical fermions) can have the identical set of quantum numbers or occupy the same quantum state simultaneously.

- ✓ **Field:** A region of space in which a force acts.

- ✓ **Frequency:** For a wave, the number of complete cycles per second.

- ✓ **Gamma rays:** Electromagnetic rays of very short wavelength, produced in radio-active decay or by collisions of elementary particles.

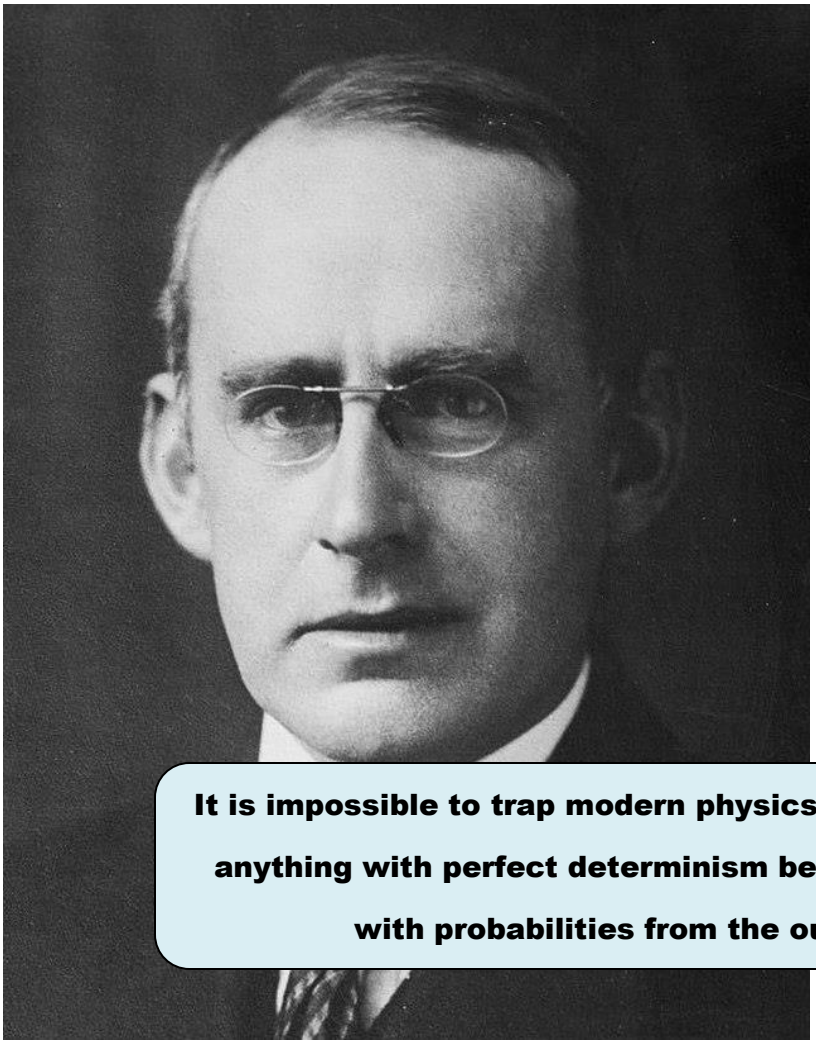
- ✓ **General relativity:** Einstein's theory of gravity based on the idea that the laws of physics should be the same for all observers, regardless of their state of motion. In general relativity, the force of gravity is not seen as a traditional force like in Newtonian physics but rather as a consequence of the curvature of four dimensional spacetime. It has been verified experimentally to better than 99.7 percent accuracy and predicts the existence of black holes and the expanding universe. The theory, however, break down at the center of a black hole or the instant of creation, where the theory predicts nonsense. To explain these phenomena, one must resort to a theory of subatomic physics.

- ✓ **Geodesic:** The shortest (or longest) path between two points.

- ✓ **Grand unification energy:** The energy above which, it is believed, the three fundamental forces of nature — the electromagnetic force, the weak nuclear force, and the strong nuclear force — become indistinguishable from each other.

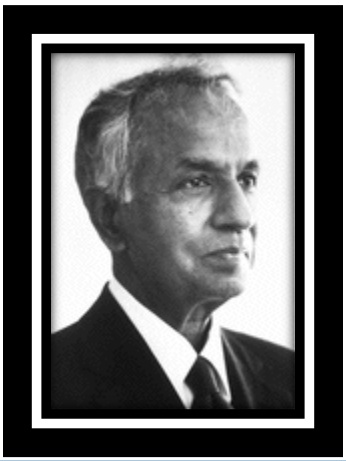
- ✓ **Grand unified theory (GUT):** A theory which unifies the electromagnetic, strong, and weak forces (but not gravity). The proton is not stable in these theories and can decay into lighter particles. **GUT theories** are inherently unstable (unless one adds super symmetry). **GUT theories** also lack gravity. (Adding gravity to GUT theories makes them diverge with infinities).

- ✓ **Imaginary time:** Time measured using imaginary numbers.



It is impossible to trap modern physics into predicting anything with perfect determinism because it deals with probabilities from the outset.

**Sir Arthur Stanley Eddington**

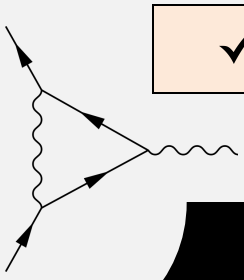


Science is a perception of the world around us. Science is a place where what you find in nature pleases you.

**Subrahmanyan Chandrasekhar**




✓ **C V Raman and other scientists of the IACS c. 1929.**



The **Raman Effect**, also known as **Raman scattering**, is a phenomenon in physics where a photon of light interacts with matter, typically a molecule, and undergoes a change in energy and direction. This effect is named after the Indian physicist **Sir C. V. Raman**, who discovered it in 1928. When a photon of light interacts with matter, it can be absorbed, reflected, or scattered. In the case of **Raman scattering**, the photon interacts with the molecule and causes it to vibrate. This vibration results in a change in the energy and direction of the photon, which is then scattered in a different direction than the incident photon. The **Raman Effect** is used in **spectroscopy** to analyze the vibrational modes of molecules, which can provide information about the chemical composition and structure of a substance. It has many applications in fields such as chemistry, materials science, and biology.



- **Energy output of the Sun:** The Sun's energy output is approximately $3.8 \times 10^{26}$ joules per second. This value represents the total energy radiated by the Sun in one second.



- **Energy released by one ton of TNT:** The energy released by one ton of TNT is approximately $4.184 \times 10^{9}$ joules.

$$\frac{3.8 \times 10^{26}\ \text{joules/second}}{4.184 \times 10^{9}\ \text{joules/ton}} \approx 9.08 \times 10^{16}\ \text{ton / second}$$

Therefore, it would take approximately $9.08 \times 10^{16}$ tons of TNT per second to match the energy output of the Sun per second.



**Albert Einstein playing the violin.**

- ✓ **Inflation:** The theory which states that the universe underwent an incredible amount of superliminal expansion at the instant of its birth i.e., A distance of one nanometer was enlarged to a quarter of a billion light-years.

- ✓ **Hyperspace:** A higher-dimensional space beyond our three spatial dimensions (length, width, and height).
- ✓ **Light cone:** A surface in space-time that marks out the possible directions for light rays passing through a given event.

- ✓ **Light year:** The distance light travels in one year, or approximately 5.88 trillion miles (9.46 trillion kilometers). **Light-year** is often used to measure the distance between stars, galaxies, and other celestial objects. **For example,** our nearest neighboring star system, **Alpha Centauri**, is located about **4.37 light-years** away from Earth. This means that the light we see from Alpha Centauri today actually left the star system about 4.37 years ago.

- ✓ $m_{down} = 5$ MeV
- ✓ $m_{up} = 2$ MeV
- ✓ $m_{strange} = 95$ MeV
- ✓ $m_{charm} = 1.3$ GeV
- ✓ $m_{bottom} = 4.2$ GeV
- ✓ $m_{top} = 170$ GeV



- ✓ (ddu) $\rightarrow m_{neutron} \approx 939.57$ MeV
- ✓ (uud) $\rightarrow m_{proton} \approx 938.28$ MeV



- ✓ **LIGO:** The **L**aser **I**nterferometry **G**ravitational-Wave **O**bservatory, a gravitational wave detector located in Washington state and Louisiana. It is specifically designed to detect cosmic gravitational waves and advance the field of gravitational wave astronomy as a powerful tool for astronomical observations.

- ✓ **LISA:** The **L**aser **I**nterferometry **S**pace **A**ntenna – a planned space-based observatory designed to detect and study gravitational waves. Gravitational waves are ripples in the fabric of spacetime caused by the acceleration of massive objects, such as black holes or neutron stars. **LISA** is a joint project of the European Space Agency **(ESA)** and

**NASA**. The mission is currently in the advanced planning stages, with a target launch date in the 2030s. It is expected to provide valuable insights into the nature of gravity, the structure of spacetime, and the astrophysical processes that generate gravitational waves.

- ✓ **Magnetic field:** The region around a magnetic substance or a moving electric charge within which the magnetic force acts..

- ✓ **Muon:** A subatomic particle identical to the electron, with an electric charge of −1e and a spin of 1/2, but with a much larger mass. It belongs to the second generation of particles found in the Standard Model.

- **Phase velocity:** $v_{phase} = \frac{\omega}{k}$

  where $\omega = \frac{E}{\hbar}$ is the angular frequency and $k = \frac{2\pi}{\lambda} = \frac{p}{\hbar}$ is the wave number

- **Group velocity:** $v_{group} = \frac{d\omega}{dk} = \frac{d(E/\hbar)}{d(p/\hbar)} = \frac{dE}{dp}$

This means that the group velocity of the particle is the rate at which the particle's energy changes with respect to its momentum.

- ✓ **Mass:** The mass of an object refers to the amount of matter it contains. It is a measure of an object's inertia, which is its resistance to changes in its state of rest or motion.

- ✓ **Microwave background radiation:** the remnant radiation from the early universe. It is considered one of the strongest pieces of evidence supporting the Big Bang theory. The cosmic microwave background radiation was first discovered in 1964 by **Arno Penzias** and **Robert Wilson**, who were awarded the Nobel Prize in Physics for their discovery. It is composed of electromagnetic photons that has been highly redshifted over time due to the expansion of the universe. The initial light emitted shortly after the Big Bang has been stretched to longer wavelengths, shifting it into the microwave range.

- ✓ **Naked singularity:** A hypothetical gravitational singularity without an event horizon.

- ✓ **Neutrino:** An extremely light (possibly massless) subatomic particle that react very weakly with other particles. **Neutrinos** primarily interact via the **weak nuclear force**, which is responsible for processes like **beta decay**. Due to their weak interactions, neutrinos can pass through ordinary matter, such as the Earth or lead shielding, without interacting with it. This property allows neutrinos to travel significant distances through space without being absorbed or scattered by intervening matter.

- ✓ **Neutron:** A subatomic particle that, together with protons, makes up the nucleus of an atom. Unlike protons, which carry a positive charge, neutrons are electrically neutral, meaning they have no net charge. **Neutrons** play a crucial role in nuclear reactors by serving as the primary particles responsible for initiating and sustaining a chain reaction.

- ✓ **Neutron star:** A incredibly dense object that form when a massive star undergoes a supernova explosion. During the explosion, the outer layers of the star are expelled, leaving behind a highly compact remnant composed primarily of neutrons. These neutrons are packed densely together, supported against gravitational collapse by the degeneracy pressure resulting from the **Pauli exclusion principle**.

- ✓ **No boundary condition:** The idea that the universe does not have a boundary, similar to the rounded surface of the Earth lacking an edge.

- ✓ **Nuclear fusion:** The process by which two nuclei collide and coalesce to form a single, heavier nucleus.
- ✓ **Nucleus:** The tiny core of an atom, which is roughly $10^{-13}$ cm across, consisting only of protons and neutrons, held together by the strong force.

$$\text{Binding energy per nucleon} = \frac{(\text{mass of individual nucleons} - \text{mass of bound nucleus})\, c^2}{\text{atomic mass number}}$$

- ✓ **Particle accelerator:** A machine — based in Geneva, Switzerland — that, using electromagnets, can accelerate moving charged particles, such as protons or electrons,

to high speeds and energies. These machines play a crucial role in various fields of scientific research, including particle physics, nuclear physics, and materials science.

- ✓ **Phase:** For a wave, the position in its cycle at a specified time: a measure of whether it is at a crest, a trough, or somewhere in between.

- ✓ **Photon:** A quantum of light (which was first proposed by **Albert Einstein** to explain the **photoelectric effect** — that is, the fact that shining light on a metal results in the ejection of electrons).

- ✓ **Planck's quantum principle:** The idea that light (or any other classical waves) can be emitted or absorbed only in discrete quanta, whose energy E is inversely proportional to their wavelength λ (i.e., $E = \frac{hc}{\lambda}$ or $E \propto \frac{1}{\lambda}$).

- ✓ **Positron:** The (positively charged) antiparticle of the electron.

- ✓ **Primordial black hole:** A black hole created in the very early universe, shortly after the Big Bang. Unlike black holes that form from the gravitational collapse of massive stars, primordial black holes would have originated from the extreme density fluctuations present during the early stages of the universe's evolution.

- ✓ **Negative energy:** Energy that is less than zero.

- ✓ **Proton:** A subatomic particle that carries a positive electrical charge and is one of the building blocks of matter, which is about 1,836 times the mass of an electron. **Protons** are stable particles, but **Grand Unification theory** predicts that they may decay over a long period of time, although experimental evidence for this decay is still lacking.

- ✓ **Pulsar:** A rotating neutron star that emits regular pulses of radio waves.

- ✓ **Quantum:** The indivisible unit in which waves may be emitted or absorbed.

- ✓ **Quark:** A subatomic particle that makes up the proton and neutron and feels the strong force. Three quarks make up a proton or neutron, and a quark and antiquark pair makes up a meson.

- ✓ **Quantum chromodynamics (QCD):** The theory that describes the interactions of quarks and gluons.

- ✓ **Quantum mechanics:** The theory developed from wave equations, Planck's quantum principle and Heisenberg's uncertainty principle. No deviation from quantum mechanics has ever been found in the laboratory. Its most advanced version today is called **quantum field theory**, which combines special relativity and quantum mechanics. A fully quantum mechanical theory of gravity, however, is exceedingly difficult.

- ✓ **Quasars:** Quasi-stellar objects. A quasar is an astronomical object located at the centers of certain galaxies, characterized by its incredibly high luminosity. It is powered by gas that spirals at high velocities into an extremely large black hole. Quasars possess the ability to surpass the combined luminosity of all the stars within their host galaxies, enabling them to remain visible even at distances spanning billions of light-years.

- ✓ **Quantum foam:** Tiny, foam like distortions of 4 dimensional fabric of space-time at the level of the Planck length.

- ✓ **According to Newtonian physics:**

$$eV = \frac{m_e v^2}{2}$$

- ✓ **According to special relativity:**

$$eV = m_e (\gamma - 1)\, c^2$$

$$\frac{eV}{m_e c^2} + 1 = \gamma \quad \text{or} \quad \frac{v}{c} = \sqrt{1 - \left(1 + \frac{eV}{m_e c^2}\right)^{-2}}$$

- ✓ **Radioactivity:** The natural and spontaneous process by which certain atomic nuclei undergo decay, transforming into different nuclei and emitting radiation in the process. This phenomenon was first discovered by **Henri Becquerel** and further studied by **Marie Curie** and her colleagues.

- ✓ **Red shift:** The reddening or decrease in frequency of light from a star that is moving away from us, due to the Doppler effect.

- ✓ **Singularity:** A point in space-time at which the space-time curvature becomes infinite – which represent a breakdown of general relativity (the classical theory of gravity), forcing the introduction of a quantum theory of gravity.

- ✓ **Singularity theorem:** A theorem that states that the universe must have started with a singularity.

- ✓ **Space-time:** A fundamental concept in physics that combines the three dimensions of space (length, width, and height) with the dimension of time into a four-dimensional framework. It is the fabric or structure in which all physical events and objects exist and evolve.

- ✓ **Spatial dimension:** The dimensions of space in which objects and events are located and measured.

- ✓ **Special relativity:** A theory developed by **Albert Einstein** in 1905 that revolutionized our understanding of space, time, and motion. It provides a framework for describing the behavior of objects moving at speeds close to the speed of light and has profound implications for our understanding of the universe. **Implications include:** time slows down, mass increases, and distances shrink the faster you move. Also, matter and energy are related via $\mathbf{E = mc^2}$**.** One of the key principles of **special relativity** is that the speed of light in a vacuum is constant and is the same for all observers, regardless of their relative motion. This constancy of the speed of light has significant implications, one of which is that it serves as an **ultimate speed limit** in the universe.

- ✓ **Spectrum:** The different colors or component frequencies that make up a wave. The study of the spectrum of light emitted or absorbed by celestial objects, such as stars,

provides valuable information about their composition, temperature, motion, and other properties. This invaluable information propels significant progress in the fields of astrophysics and cosmology.

**The intensity of an electromagnetic wave:**

$$I \propto E_0^2$$

(expressed in terms of the maximum electric field strength $E_0$)

Since $c = \frac{E_0}{B_0}$ :

$$I \propto B_0^2$$

(expressed in terms of the maximum magnetic field strength $B_0$)

$$I \propto E_0 \, B_0$$

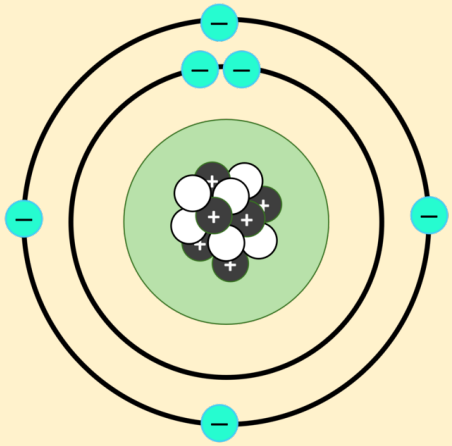
(expressed in terms of both the maximum electric field strength $E_0$ and the maximum magnetic field strength $B_0$)

- ✓ **Spin:** A fundamental property of elementary particles such as electrons, protons, and neutrons. It is a quantum mechanical property that describes the intrinsic angular momentum of a particle.

- ✓ **Stationary state:** One that is not changing with time.

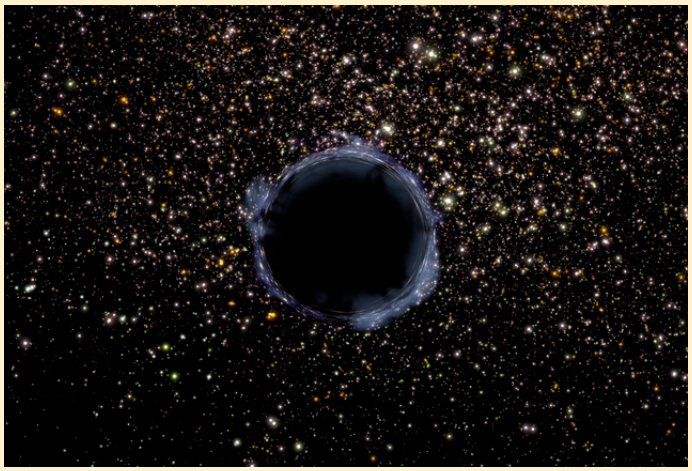
- ✓ **Supernova:** A powerful and catastrophic event that occurs at the end of a massive star's life cycle. It is an extremely energetic explosion that releases an immense amount of energy, outshining an entire galaxy for a short period.

| External Reality Hypothesis (ERH) | Mathematical Universe Hypothesis (MUH) |
|---|---|
| There exists an external physical reality completely independent of us human beings. | External physical reality is a mathematical structure. |

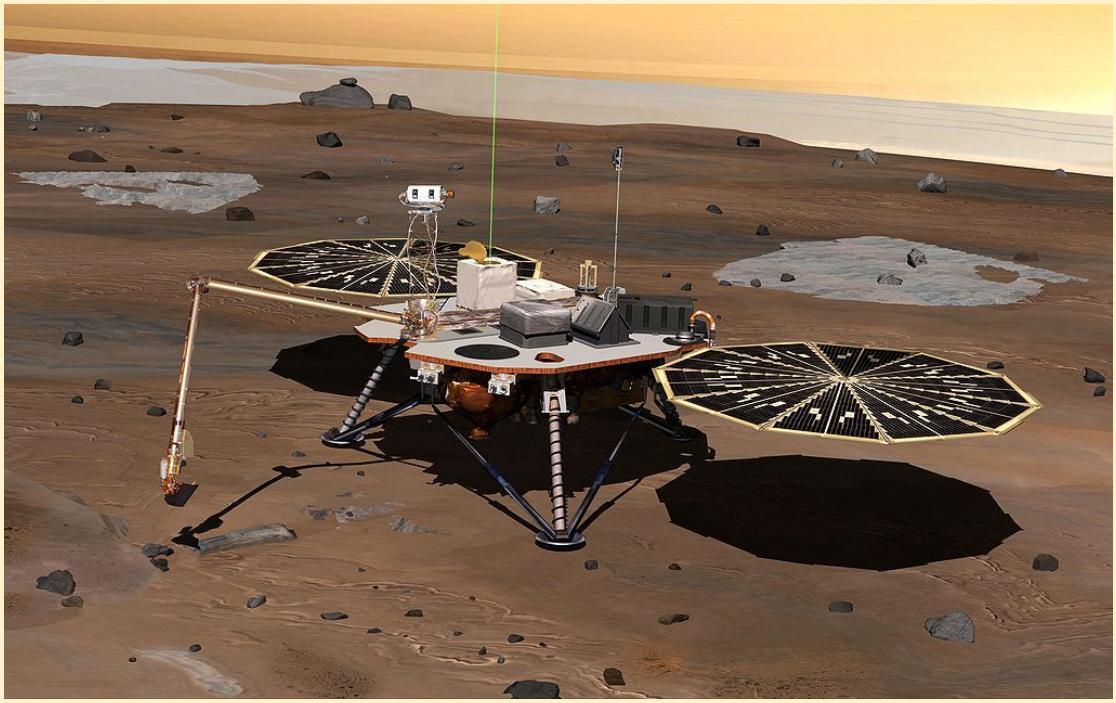


**The Bohr model of a Carbon atom** – 6 protons, 6 neutrons, and 6 electrons. It has 4 valence electrons.

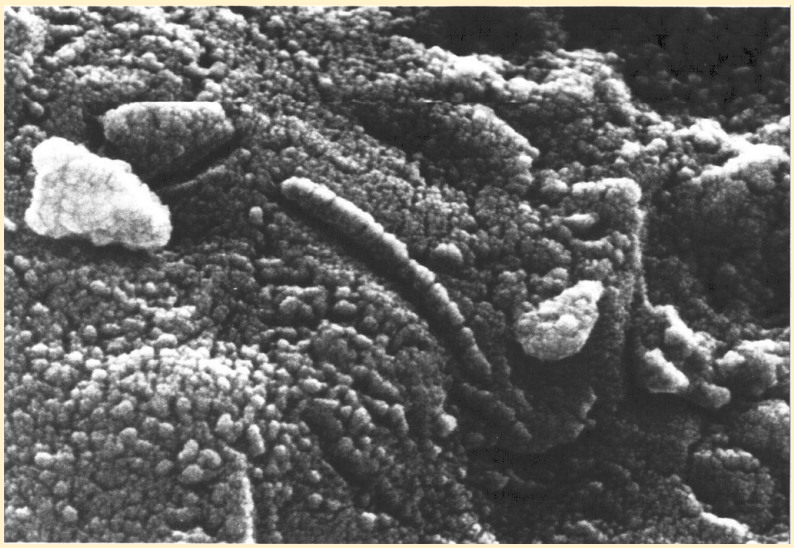
| QED | QCD |
|---|---|
| Quantum theory of electromagnetic interactions mediated by exchange of photons. | Quantum theory of strong interactions mediated by exchange of gluons between quarks. |



✓ **Black Hole in a Globular Cluster**



An artistic depiction of the **Phoenix spacecraft** – a real mission conducted by NASA's Mars Scout Program. It successfully landed on Mars in 2008 and played a crucial role in studying the planet's polar region. The mission's primary objective was to search for water ice and assess the planet's potential habitability.



The discovery of potential bacteria-like structures in the meteorite fragment **ALH84001** was indeed a significant event in scientific history. This finding generated considerable interest and sparked debates regarding the possibility of extraterrestrial life.

- ✓ **String theory:** A theoretical framework in physics that aims to provide a unified description of all fundamental forces and particles in the universe. It suggests that at the most fundamental level, all particles are composed of tiny, vibrating strings of energy. These strings can have different modes of vibration, which correspond to different particle properties, such as mass and charge.

- ✓ **Strong force:** The strongest of the four fundamental forces, with the shortest range of all. It holds the quarks together within protons and neutrons, and holds the protons and neutrons together to form atoms.

The size of a black hole that contained only as much mass as a typical pickup truck (about 6000 kg) is calculated using the formula:

$$R_s = \frac{2GM}{c^2} = \frac{2 \times 6.673 \times 10^{-11} \text{Nm}^2/\text{kg}^2 \times 6000 \text{ kg}}{(299792458 \text{ m/s})^2}$$

$$R_s \approx 8.909 \times 10^{-24} \text{ m}$$

For comparison, the **Classical electron radius** is about $2.8179 \times 10^{-15}$ m.

- ✓ **Steady state theory:** The theory which states that the universe had no beginning or end (infinite in both space and time). It proposed that as the universe expands, new matter is continuously created throughout space to fill in the gaps left by the expansion. This continuous creation of matter ensures that the overall density of the universe remains constant over time.

- ✓ **Uncertainty principle:** Also known as Heisenberg's uncertainty principle or the principle of indeterminacy, is a fundamental concept in quantum mechanics. It states that certain pairs of physical properties, such as position and momentum, cannot both be precisely determined or known simultaneously with arbitrary accuracy. This means

that the more precisely you try to measure the position of a particle, the less precisely you can know its momentum, and vice versa.

- ✓ **Virtual particles:** According to quantum field theory, the vacuum is not an empty void but rather a sea of constantly fluctuating fields. These fluctuations can give rise to the creation of particle-antiparticle pairs, which are the **virtual particles**. They can spontaneously appear from the vacuum, exist for a brief moment, and then annihilate each other, returning their borrowed energy back to the vacuum. The **Heisenberg uncertainty principle** limits the duration of their fleeting existence and the distance they can travel. The existence of virtual particles is a purely quantum-mechanical phenomenon.

- ✓ **Wave-particle duality:** The concept in quantum mechanics that there is no distinction between waves and particles; particles may sometimes behave like waves, and waves like particles.

- ✓ **Wavelength:** For a wave, the distance between two adjacent troughs or two adjacent crests.

- ✓ **Weak force:** One of the fundamental forces of nature – which is carried by the $W^-$ and $Z^-$ bosons – that is responsible for certain types of radioactive decay and plays a crucial role in the interactions of elementary particles. The weak force is involved in processes such as **beta decay**, where a neutron can transform into a proton while emitting an electron and an electron antineutrino **(beta-minus decay)**, or a proton can transform into a neutron while emitting a positron and an electron neutrino **(beta-plus decay)**. These processes involve the exchange of W bosons, which carry the weak force.

- ✓ **Weight:** The force exerted on an object by a gravitational field. It is proportional to the mass of the object but is not the same thing as mass itself. **Weight** can vary depending on the strength of the gravitational field. For example, an object would weigh less on the Moon compared to Earth because the Moon has a weaker gravitational pull. However, the mass of the object remains the same in both situations.

- ✓ **White dwarf:** When a star depletes its nuclear fuel, it undergoes gravitational collapse. In the case of stars with low to medium mass (typically up to around 8 times the mass

of the Sun), the core contracts while the outer layers are expelled, forming a planetary nebula. The remaining core, primarily composed of carbon and oxygen, transforms into a dense and hot object called a **white dwarf**. White dwarfs are characterized by their high temperatures and faint brightness. As they cool down over time, they emit thermal radiation. Initially, they appear very hot and luminous, but as they age, they gradually cool and fade away, eventually becoming **"black dwarfs"** that no longer emit significant radiation.

**From the equation of motion:**

$$v^2 = u^2 + 2ad$$

- ✓ v → Final velocity
- ✓ u → initial velocity
- ✓ a → acceleration
- ✓ d → displacement

$$ad = \frac{v^2 - u^2}{2}$$

The work done by the force **F**, which is constant in both magnitude and direction and is parallel to the velocity of the particle is given by:

$$W = F \times d$$

According to **Newton's second law of motion**:

$$F = ma$$

$$W = m \times ad = \frac{mv^2 - mu^2}{2}$$

✓ $W = \Delta KE$

**Work-Energy Theorem**

The work done on an object is equal to the change in its kinetic energy.

The **angular momentum** " L" of an electron in an atom is related to the **angular momentum quantum number** " $l$ " through the following equation:

Determines the shape of the electron's orbital

$$L = \sqrt{l(l+1)}\,\hbar$$

where $\hbar = \frac{h}{2\pi}$ is the reduced Planck's constant. For example, for $l = 2$, we see that:

$$L = \sqrt{2(2+1)}\,\hbar = \sqrt{6}\,\hbar \approx 2.58\times10^{-34}\ \text{Js}.$$

## ✓ Pauli Exclusion Principle

A fundamental principle in quantum mechanics that states that no two identical fermions can occupy the same quantum state simultaneously. It was formulated by the Austrian physicist Wolfgang Pauli in 1925.



# Did you know?

- The maximum number of electrons that can be in a subshell is $2(2l + 1)$.
- The maximum number of electrons that can be in a shell is $2n^2$.

where n is the principal quantum number and $l$ is the angular momentum quantum number

✓ Nuclear radius = $r_0 A^{1/3}$

where $r_0$ = 1.2 fm and A is the mass number of the nucleus.

Let's consider an example to calculate the nuclear radius for a specific nucleus. Suppose we want to calculate the nuclear radius for a nucleus with a mass number A = 40.

Nuclear radius = $(1.2 \times 10^{-15}$ meters$) \times (40)^{1/3}$

Nuclear radius ≈ 4.103 fm

Therefore, for a nucleus with a mass number of 40, the estimated **nuclear radius** would be approximately $4.103 \times 10^{-15}$ meters.

**Proton decay** is a hypothetical process predicted by certain **grand unification theories**, such as the SU(5) Georgi-Glashow model and SO(10), as well as their **supersymmetric variants**. These theories aim to unify the electromagnetic, weak, and strong nuclear forces into a single framework. According to these theories, the **proton**, which is a stable particle in the **Standard Model of particle physics**, can decay into lighter particles. One of the most common proposed decay modes is the decay of a proton into a **positron** (the antimatter counterpart of an electron) and a **neutral pion** (a meson composed of an up quark and an anti-up quark). The **neutral pion** itself is an unstable particle and rapidly decays into two gamma ray photons. **Gamma rays** are high-energy photons. Thus, the **decay process of a proton** in these theories is envisioned as follows:

Proton → Positron + Neutral Pion

Neutral Pion → Two Gamma Ray Photons

However, it is important to note that despite the theoretical predictions and the elegance of these grand unification theories, there is currently no experimental evidence for **proton decay**. It is worth mentioning that proton decay is a topic of active research, and future experiments aim to further explore this possibility. If **proton decay** is observed, it would have profound implications for our understanding of particle physics and the fundamental forces of nature.







**Maria Goeppert Mayer** was a renowned physicist known for her significant contributions to the field of nuclear physics. She played a crucial role in developing the nuclear shell model, which provides a framework for understanding the structure and behavior of **atomic nuclei**. Her work on the **nuclear shell model**, which she proposed in 1949, demonstrated that atomic nuclei can be thought of as having energy levels and shells analogous to the electron energy levels and shells in an atom. This model helped explain various nuclear phenomena, such as nuclear stability, isotopes, and nuclear reactions. In recognition of her groundbreaking research, **Maria Goeppert Mayer** was awarded the **Nobel Prize in Physics in 1963**, becoming the second woman in history to receive this prestigious honor. The first woman to win a Nobel Prize in physics was **Marie Curie**, who won it twice, in 1903 and 1911. **Maria Goeppert Mayer's contributions and achievements** continue to inspire and pave the way for women in the field of physics. In her honor, the **Maria Goeppert-Mayer Award** was established in 1986, recognizing outstanding achievements by early-career women physicists.



Maria Goeppert Mayer walking into the Nobel ceremony with King Gustaf VI Adolf of Sweden in 1963

$$R_S = \frac{2GM}{c^2}$$

**Black holes** are very small, as evidenced by the fact that G is small and $c^2$ is large.

Quantum Chromodynamics (QCD) is the part of the Standard Model of particle physics that describes the strong nuclear force, which holds quarks and gluons together to form protons, neutrons, and other particles.

It was developed in the 1960s and 1970s by physicists **Murray Gell-Mann** and **George Zweig**, who independently proposed the existence of quarks.

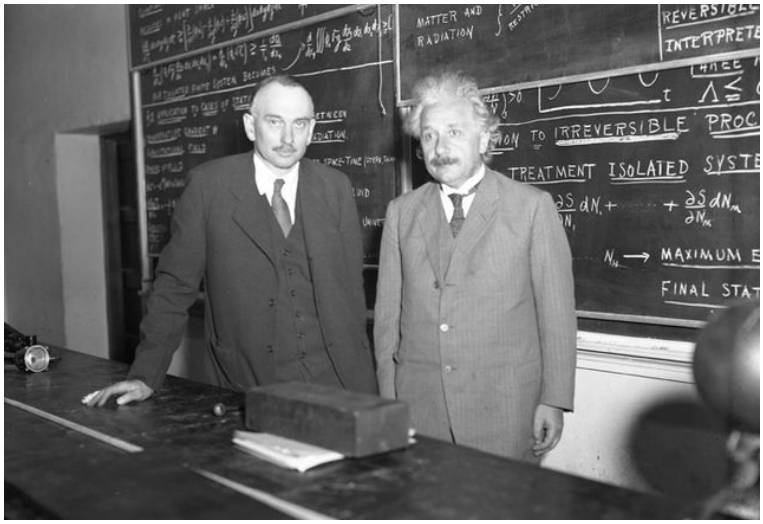
Its mathematical framework is based on the **principles of quantum mechanics** and **special relativity**, and it involves the use of a field theory known as a **gauge theory.**

It predicts the existence of **exotic hadrons**, which are particles that contain more than three quarks or antiquarks. Examples of **exotic hadrons** include **pentaquarks**, which contain four quarks and one antiquark, and **tetraquarks**, which contain two quarks and two antiquarks.

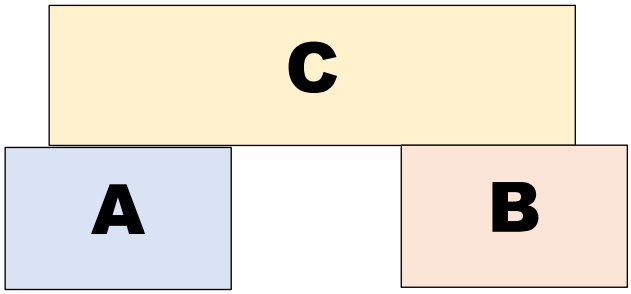
It predicts the existence of **asymptotic freedom**, which means that at high energies, the strong force becomes weaker and **quarks –** which are the fundamental constituents of protons, neutrons, and other hadrons – move more freely within these particles.

It predicts the existence of **color confinement**, which means that quarks and gluons cannot exist as isolated particles.

It has been used to study the properties of quark-gluon plasma, which is a state of matter that exists at very high temperatures and densities.

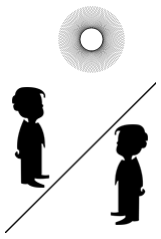



Richard C. Tolman and Albert Einstein at California Institute of Technology, Pasadena, 1932




## ✓ Zeroth law of thermodynamics

If two bodies A and B are separately in thermal equilibrium with a third body C, then A and B are also in thermal equilibrium with each other.



## First law of thermodynamics

- dU = dQ + dW (the work done on the system)
- dU = dQ – dW (the work done by the system)



| | |
|---|---|
| **Gravitational Force** | attractive only |
| **Electromagnetic Force** | attractive and repulsive |
| **Weak Nuclear Force** | attractive and repulsive |
| **Strong Nuclear Force** | attractive and repulsive |

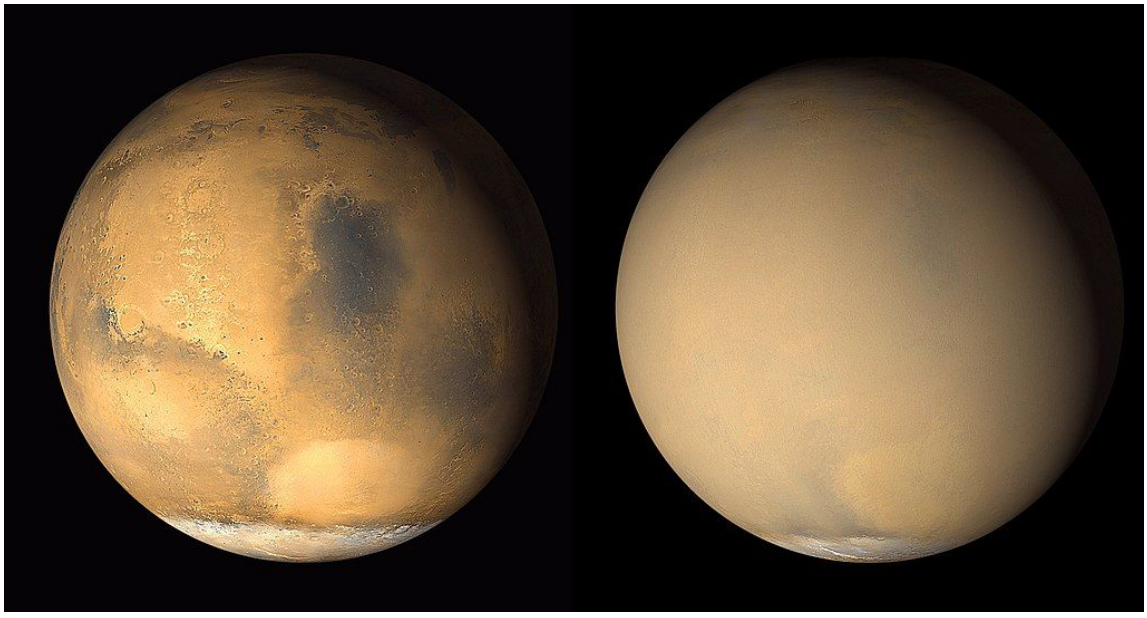


**Airy-0**, a crater located within the larger Airy Crater on Mars, played a crucial role in establishing the prime meridian on the planet. With a diameter of approximately 0.5 km (0.3 mile), this crater resides within Sinus Meridiani, a dark area that was among the first distinct features to be recognized on Mars.

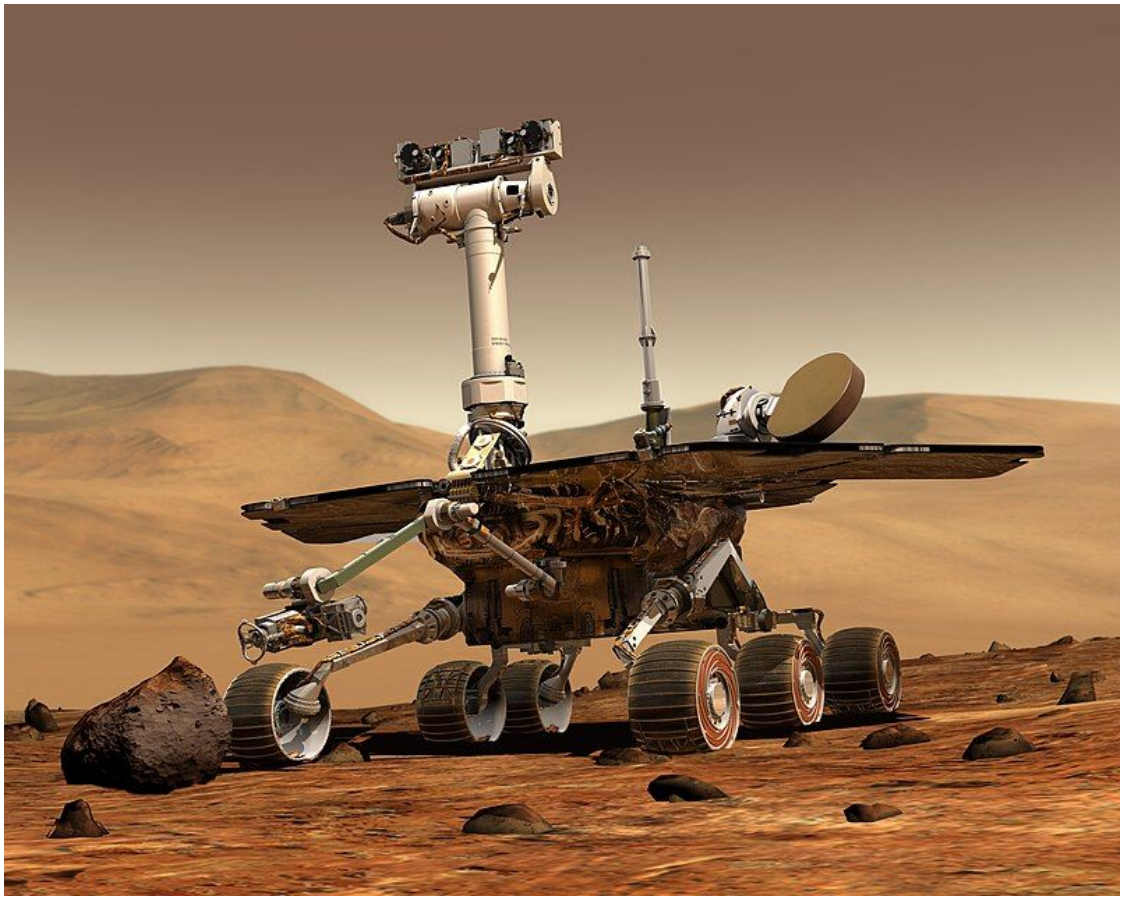
| | | |
|---|---|---|
| Isobaric | Constant pressure | $W = P\Delta V$ |
| Isochoric | Constant volume | $W = 0$ |
| Isothermal | Constant temperature | $Q = W$ |
| Adiabatic | No heat transfer | $Q = 0$ |



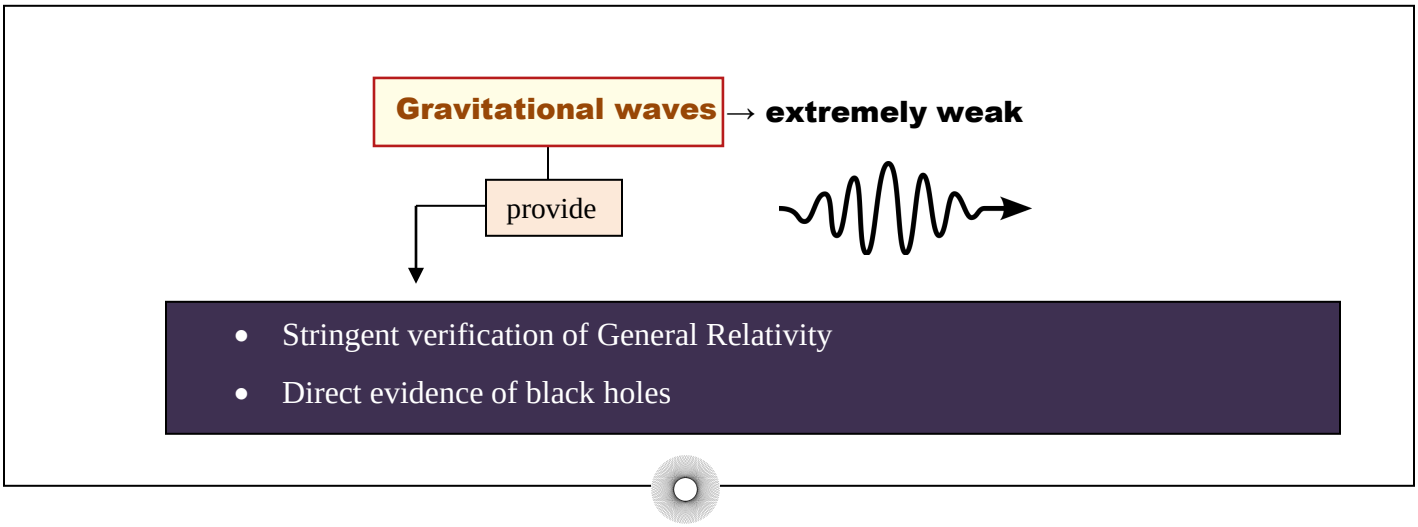
On June 26, 2001, **NASA's Hubble Space Telescope** captured an image of **Mars** at a distance of around 68 million kilometers (43 million miles) from Earth. This marked the closest proximity between Mars and Earth since 1988.



The **Mars Global Surveyor** captured two distinct images in 2001, showcasing the stark contrast between Mars without a dust storm in June (on the left) and Mars engulfed in a global dust storm in July (on the right).



An artist's rendition depicts a **NASA Mars Exploration Rover** situated on the Martian surface. The rover, designed by **NASA**, is shown exploring the red planet as it conducts scientific investigations and gathers valuable data about Mars' geology, atmosphere, and potential for past or present habitability.



## ✓ The everlasting goals of particle physics

**What are the fundamental building blocks of Nature?**

**What are the interactions between them?**

**Where does the mass of the particles originate?**

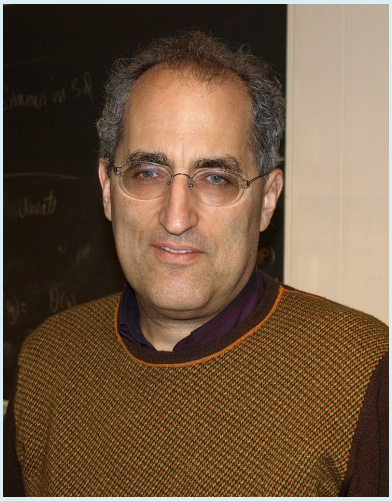
**What is the structure of space and time?**

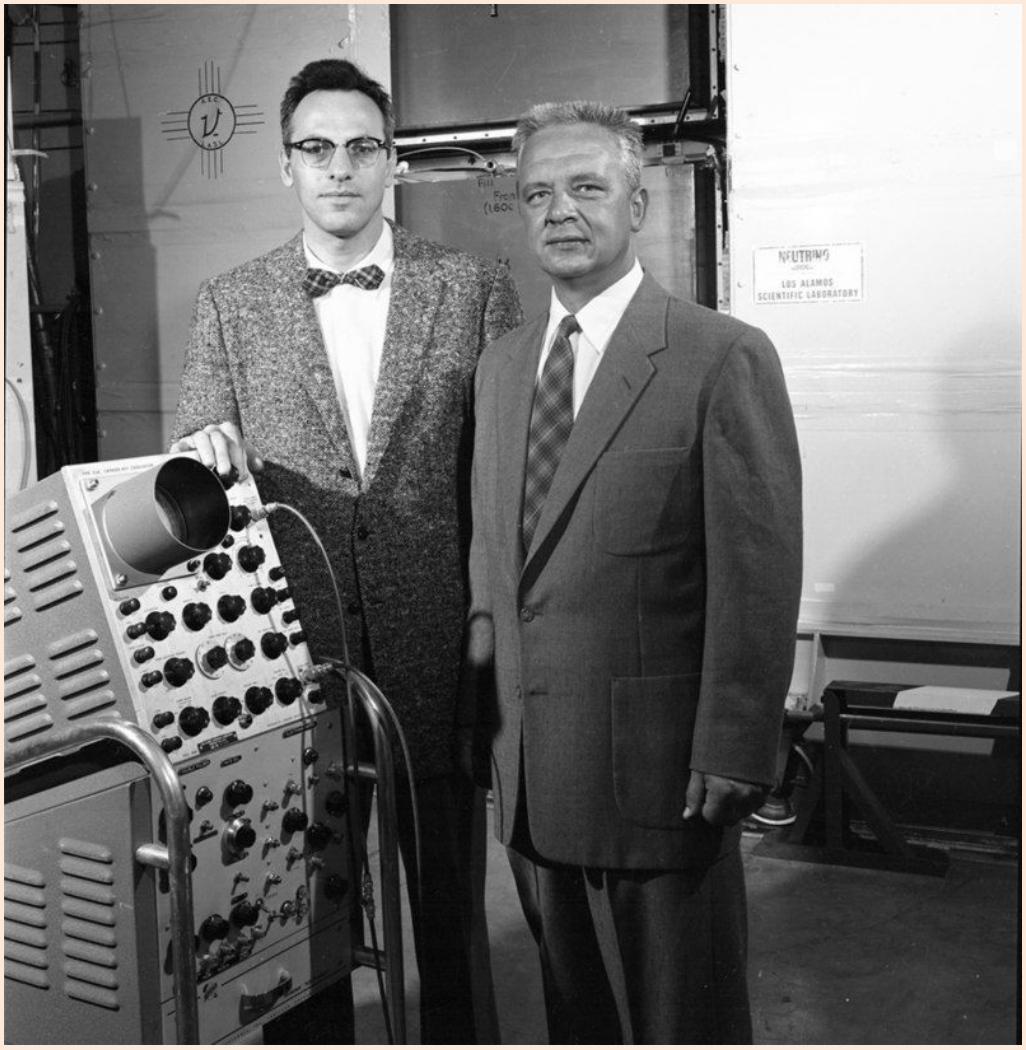
**What is dark matter? Or even dark energy?**

**Why is antimatter different from matter?**

**Particle physics is a modern name for centuries old effort to understand the laws of Nature**

**– Edward Witten (String Theorist)**



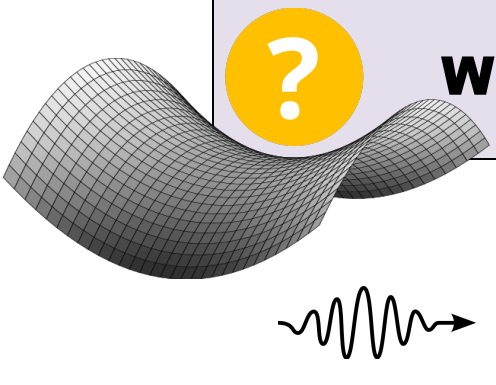



**Dr. Clyde Cowan** and **Dr. Frederick Reines** performed an experiment in 1956 called the "**Reines-Cowan experiment,"** which detected neutrinos for the first time and provided important evidence for the validity of the laws of conservation of energy and conservation of momentum in nuclear reactions involving neutrinos. For this groundbreaking work, **Cowan and Reines** were awarded the **Nobel Prize in Physics in 1995**. The discovery of the neutrino and the Reines-Cowan experiment remain important contributions to the field of particle physics.

**What is the universe made of?**

**What holds the universe together?**

**Where did we come from?**





**3 generations of quarks and leptons + force carriers**

Essentially all data we have today agrees with **Standard Model**

**The Standard Model:**

- Gauge Invariance
- The Higgs Mechanism
- Symmetries …

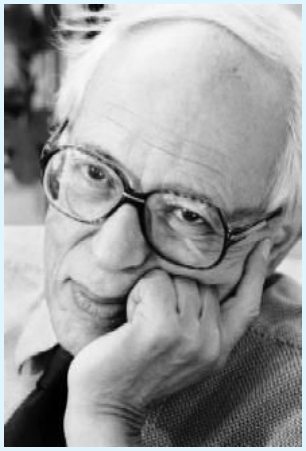
**Abraham Pais and Sam Treiman first used the term "Standard Model" in 1975 to refer to the electroweak theory with four quarks.**

Despite all its successes, many questions unanswered by **Standard Model** – Why 3 generations, particle masses, why do the generations mix …

✓ **Are there still smaller particles?**

**The Large Hadron Collider will address these questions!**

?



**Abraham Pais** (1918−2000) was a Dutch-American physicist and science historian who made important contributions to the field of theoretical physics, particularly in the area of quantum mechanics. He received his Ph.D. in physics from the **University of Utrecht** in the **Netherlands** in 1941 and worked at the Institute for Advanced Study in Princeton, New Jersey, where he collaborated with several leading physicists of his time, including **Albert Einstein** and **Robert Oppenheimer**. **Pais** authored several influential books on the history of science, including **"Subtle is the Lord: The Science and Life of Albert Einstein,"** which is considered a definitive biography of Einstein. Pais also wrote books on the history of quantum mechanics, including **"Inward Bound: Of Matter and Forces in the Physical World,"** which explores the development of quantum mechanics from the 1920s to the 1950s. **Pais** received numerous honors and awards for his contributions to physics and the history of science, including the **National Medal of Science**, the highest scientific honor in the United States, in 1986.



**Bust of Democritus (c.460 – c.370 BC), Ancient Greek philosopher**

By convention ['nomos'] sweet is sweet, bitter is bitter, hot is hot, cold is cold, color is color; but in truth there are only atoms and the void.

**– Democritus**



Quantum Chromodynamics (QCD) is the part of the Standard Model of particle physics that describes the interaction between light and matter.

It was developed by **Richard Feynman**, **Julian Schwinger**, **and Sin-Itiro Tomonaga** in the 1940s, and is considered to be one of the most successful and accurate theories in all of physics.

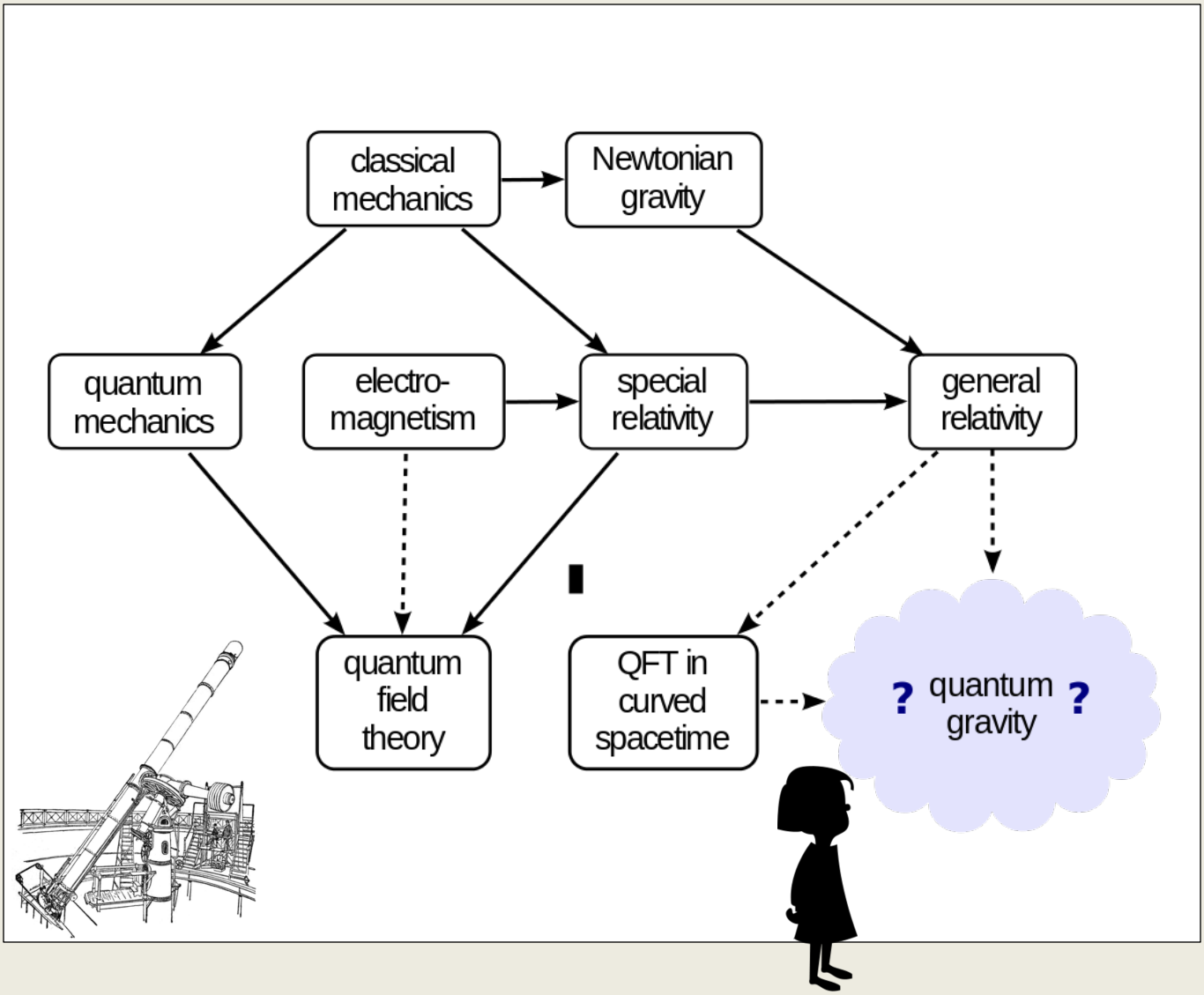
It combines the **principles of quantum mechanics** and **special relativity** to explain how electrons and photons interact with each other.

It predicts the existence of **virtual particles**, which are particles that exist only fleetingly and cannot be directly observed. Electrically charged particles interact by exchanging **virtual photons**.

It predicts that the electric charge of a particle is **quantized**, meaning that it can only take on certain discrete values. The smallest possible value of electric charge is the **charge of the electron**.

It predicts that the vacuum has a **non-zero energy density**, known as the vacuum energy.

It describes the behavior of electrically charged particles such as electrons and positrons, as well as the **electromagnetic field** that surrounds them. It also provides a framework for understanding the behavior of particles in the presence of a strong magnetic field, as in the case of the magnetic fields produced by **neutron stars** and **black holes**.

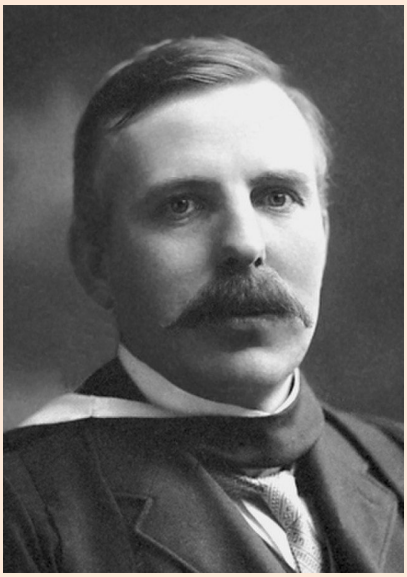



✓ **Diagram illustrating quantum gravity's position within the hierarchy of physics theories**

## Historical Landmarks of Particle Physics

- **1897: Electron discovered by J.J. Thompson**

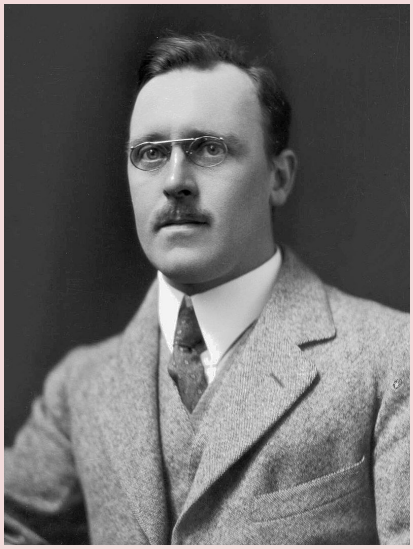
- **1899:** Alpha particle discovered by Ernest Rutherford in uranium radiation
- **1900:** Gamma ray (i.e. photon) discovered by Paul Villard in uranium decay.
- **1911:** Atomic nucleus identified by Ernest Rutherford, based on scattering observed by Hans Geiger and Ernest Marsden.



Ernest Rutherford



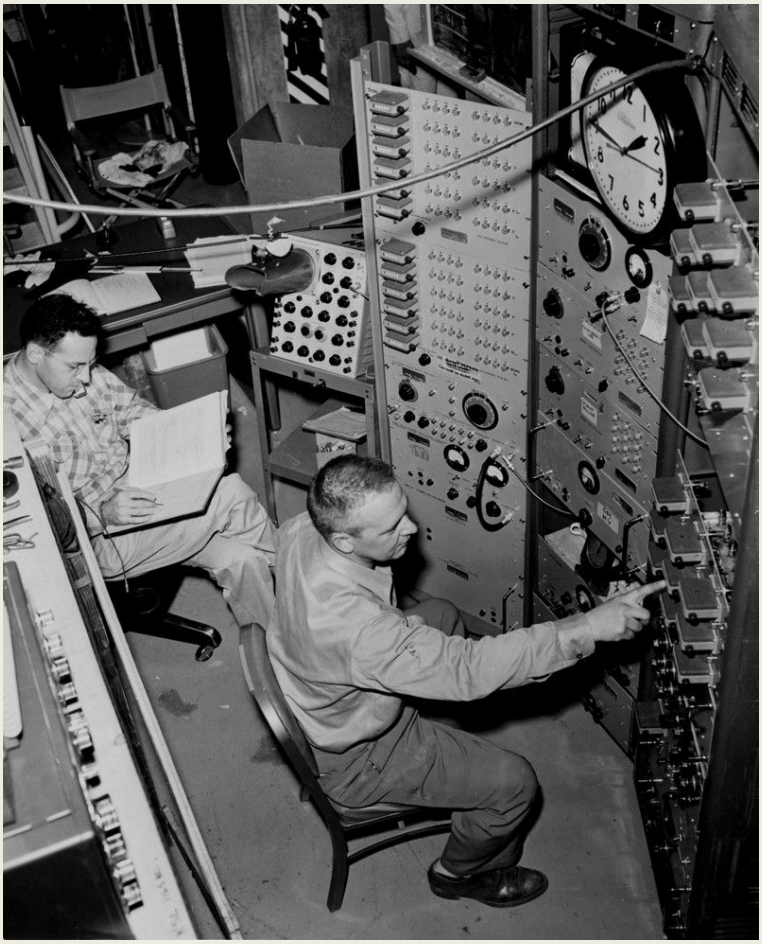
Hans Geiger



Ernest Marsden

- **1919:** Proton discovered by Ernest Rutherford
- **1932:** Neutron discovered by James Chadwick
- **1932:** Positron discovered by Carl D. Anderson (proposed by Paul Dirac in 1927)
- **1937:** Muon discovered by Seth Neddermeyer, Carl Anderson, J.C. Street, and E.C. Stevenson, using cloud chamber measurements of cosmic rays. (It was mistaken for the pion until 1946)

- **1947: Pion discovered by Cecil Powell (predicted by Hideki Yukawa in 1934)**
- **1947: Kaon, the first strange particle, discovered by G.D. Rochester and C.C. Butler**
- **1955: Antiproton discovered by Owen Chamberlain, Emilio Segre, Clyde Wiegand, and Thomas Ypsilantis**
- **1956: Neutrino detected by Frederick Reines and Clyde Cowan (proposed by Wolfgang Pauli in 1931 to explain the apparent violation of energy conservation in beta decay)**



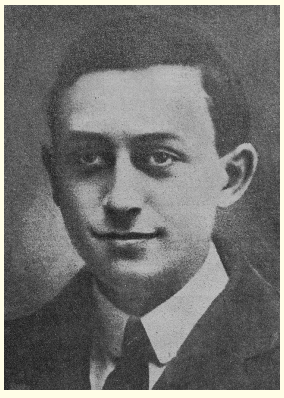
Clyde Cowan conducting the neutrino experiment, (c. 1956)

- **1962:** Muon neutrino proved distinct from electron neutrino by group headed by Leon Lederman
- **1964:** Higgs boson predicted as a result of a mechanism for electroweak symmetry breaking proposed by Peter Higgs (remains hypothetical as of 2005, but widely expected to be found at the Large Hadron Collider at CERN in the early 2010s)
- **1969:** Partons (internal constituents of hadrons) observed in deep inelastic scattering experiments between protons and electrons at SLAC; this was eventually associated with the quark model (predicted by Murray Gell-Mann and George Zweig in 1963) and thus constitutes the discovery of the up quark, down quark, and strange quark.
- **1974:** J/Ψ particle discovered by groups headed by Burton Richter and Samuel Ting, demonstrating the existence of the charm quark (proposed by Sheldon Glashow, John Iliopoulos, and Luciano Maiani in 1970)
- **1975:** Tau lepton discovered by group headed by Martin Perl
- **1977:** Upsilon particle discovered at Fermilab, demonstrating the existence of the bottom quark (proposed by Kobiyashi and Maskawa in 1973)
- **1979:** Gluon observed in three jet events at DESY.
- **1983:** W and Z bosons discovered by Carlo Rubbia, Simon van der Meer, and the CERN UA-1 collaboration (widely expected, predicted in detail by Sheldon Glashow, Abdus Salam, and Steven Weinberg in the 1960s)

- **1995:** **Top quark discovered at Fermilab**
- **2000:** **Tau neutrino proved distinct from other neutrinos at Fermilab**



**The Italian physicist Enrico Fermi sitting with his wife Laura Capon in his office at the Institute for Nuclear Studies. Los Alamos, 1954**



Enrico Fermi

**Fermium, element with atomic number 100, was named after Enrico Fermi in recognition of his contributions to nuclear physics.**

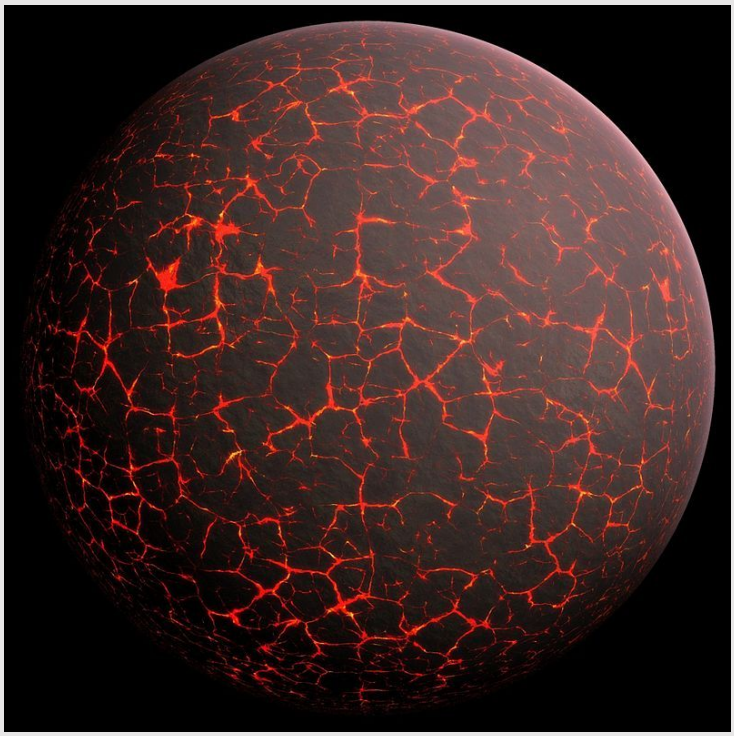
**100**

# Fm

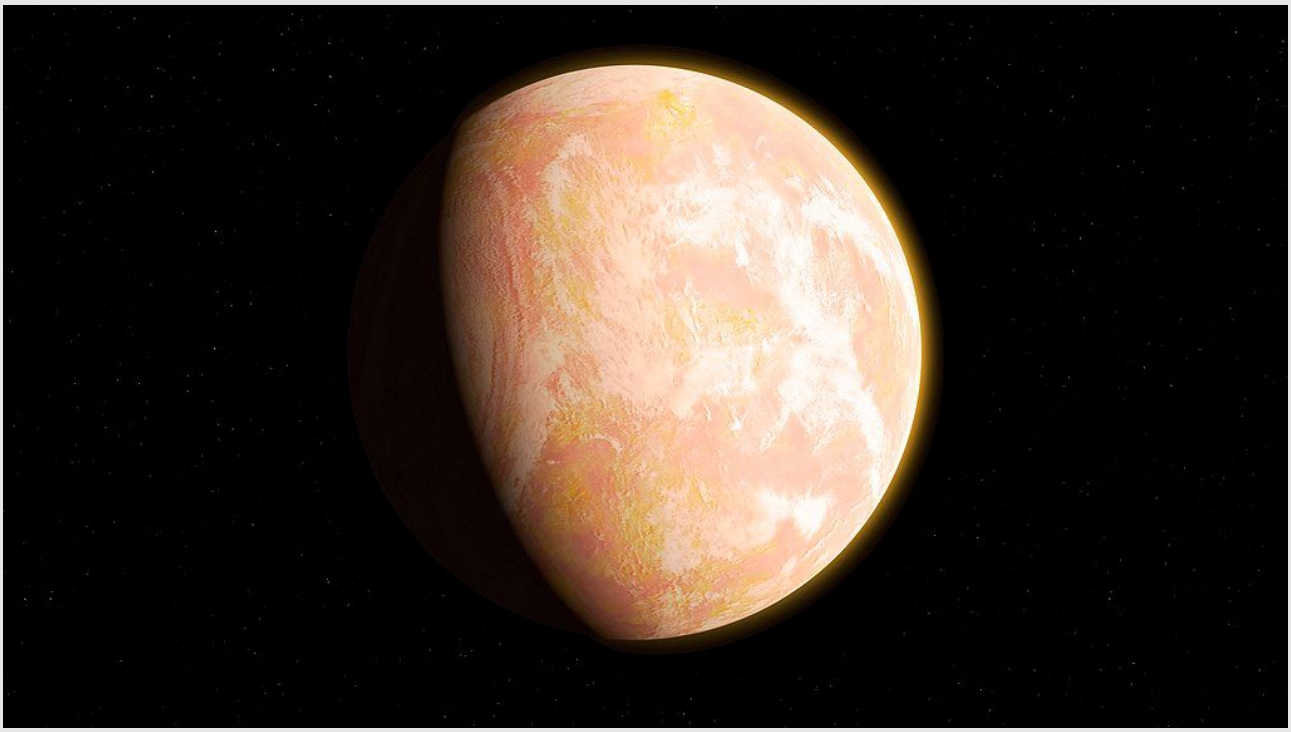
$[Rn]\ 5f^{12}\ 7s^{2}$

**Fermium**

**(257)**



During its early stages, the planet Earth existed in a significantly hotter and inhospitable state, making it unsuitable for any forms of life.



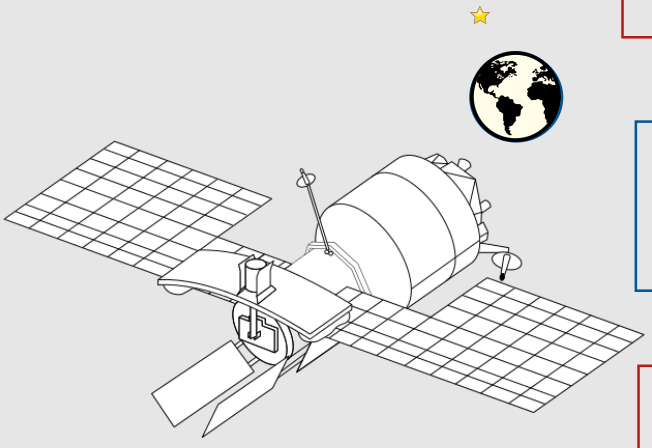
The artist's depiction of the **early Earth** shows it as a pale orange dot, reflecting the possibility that it appeared orange due to its hazy and methane-rich prebiotic second atmosphere. During this stage, Earth's atmosphere resembled the composition found in today's atmosphere of Titan.

The strengths of the electric and magnetic parts of the **electromagnetic wave** are related by:

$$\frac{E}{B} = c$$

✓ Magnetic field **B** is very weak relative to the electric field **E**

If a satellite moves in a circular orbit around the Earth with speed $v = \frac{2\pi r}{T}$, then the satellite's altitude above the Earth's surface is given by:



$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

- M → Earth's mass
- m → satellite's mass
- r → satellite's orbital radius
- R → Earth's radius

$$r = \frac{GM}{v^2}$$

$$h = r - R$$

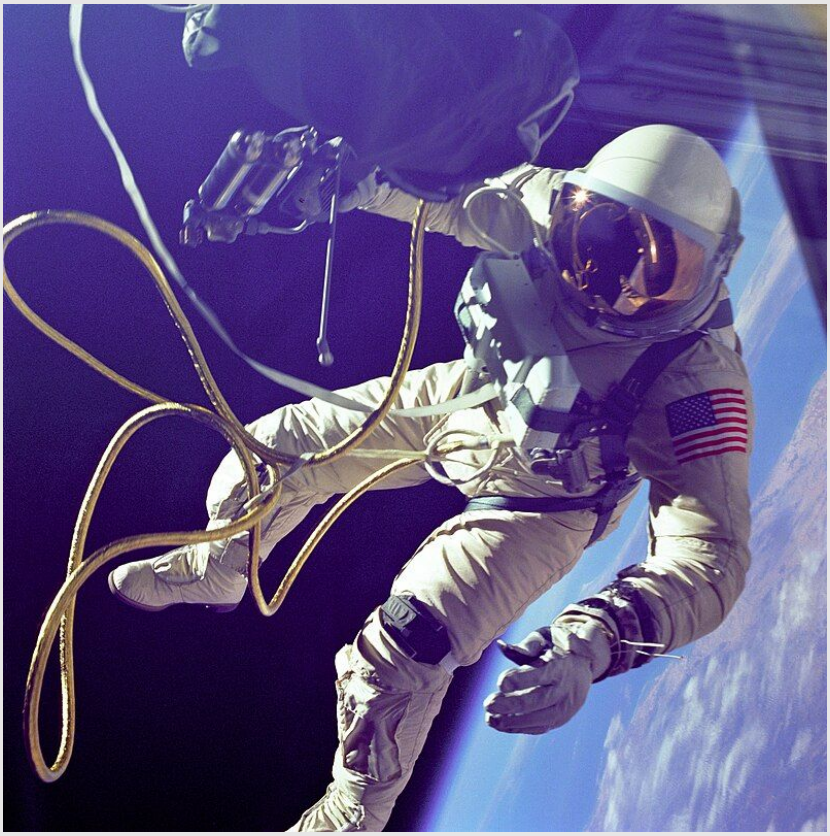


$$h = \frac{GM}{v^2} - R$$

The satellite's altitude above the Earth's surface

## Human spaceflight

The act of sending humans into space to conduct scientific research, exploration, or other activities beyond the Earth's atmosphere. It involves designing and launching spacecraft capable of carrying astronauts safely into space, providing life support systems for the astronauts, and ensuring their safe return to Earth.



**Edward H. White II** achieved a significant milestone in space exploration on June 3, 1965, when he became the first **American astronaut** to conduct a **spacewalk** (also known as an extravehicular activity or EVA) during the **Gemini 4 mission**. This historic event involved **Edward White** venturing outside the orbiting **Gemini 4 spacecraft**, where he experienced weightlessness and floated freely in the vast expanse of space.



In this artistic representation, we see a satellite probe engaged in a fascinating mission of mining a near-Earth asteroid.

## How much positive and negative charge is there in a 1 kg of water?

**The molecular mass of water is:**

**2 × (atomic mass of hydrogen)** + atomic mass of oxygen

**2 × (1.00794 g/mol)** + 15.9994 g/mol = 18.01528 g/mol

Thus, one mole (= $6.023 \times 10^{23}$ molecules) of water has a mass of 18.01528 grams. Therefore the number of molecules in 1 kg of water is $\frac{1000}{18.01528} \times 6.023 \times 10^{23}$. Each molecule of water contains two hydrogen atoms and one oxygen atom, i.e., 10 electrons and 10 protons. Hence the total positive charge is equal to:

$$\frac{1000}{18.01528} \times 6.023 \times 10^{23} \times 10 \times 1.602 \times 10^{-19}\ \text{C} = 5.35 \times 10^{7}\text{C}.$$

and the total negative charge is equal to:

$$\frac{1000}{18.01528} \times 6.023 \times 10^{23} \times 10 \times (-1.602 \times 10^{-19}\ \text{C}) = -5.35 \times 10^{7}\text{C}.$$

## Gravitational potential energy:

$$U_G = \frac{Gm_1m_2}{r}$$

Planck energy is the maximum possible energy that can be attained by a single particle

- $m_1 = m_2 = \sqrt{\frac{\hbar c}{G}}$
- $r = \sqrt{\frac{\hbar G}{c^3}}$

$$U_G = \sqrt{\frac{\hbar c^5}{G}}$$

✓ **Planck energy** is the gravitational potential energy between two bodies of 1 Planck mass each that are being separated by a distance equal to the Planck length.

## Electric potential energy:

$$U_E = \frac{q_1q_2}{4\pi\varepsilon_0 r}$$

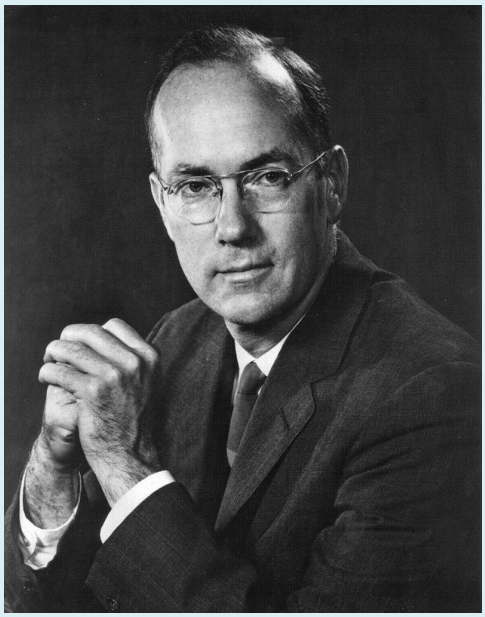
- $q_1 = q_2 = \sqrt{4\pi\varepsilon_0\hbar c}$
- $r = \sqrt{\frac{\hbar G}{c^3}}$

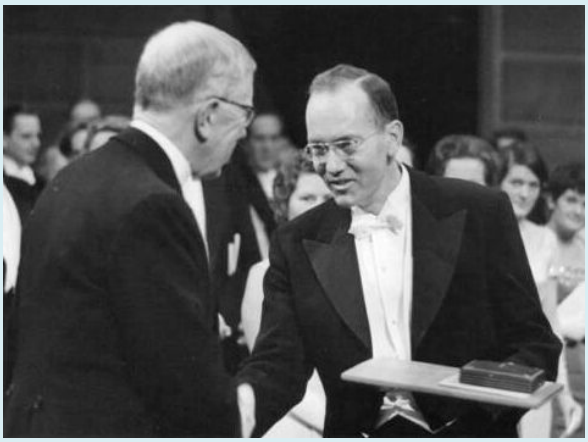
$$U_E = \sqrt{\frac{\hbar c^5}{G}}$$

✓ **Planck energy** is the electrical potential energy between two point charges of 1 Planck charge each that are being separated by a distance equal to the Planck length.



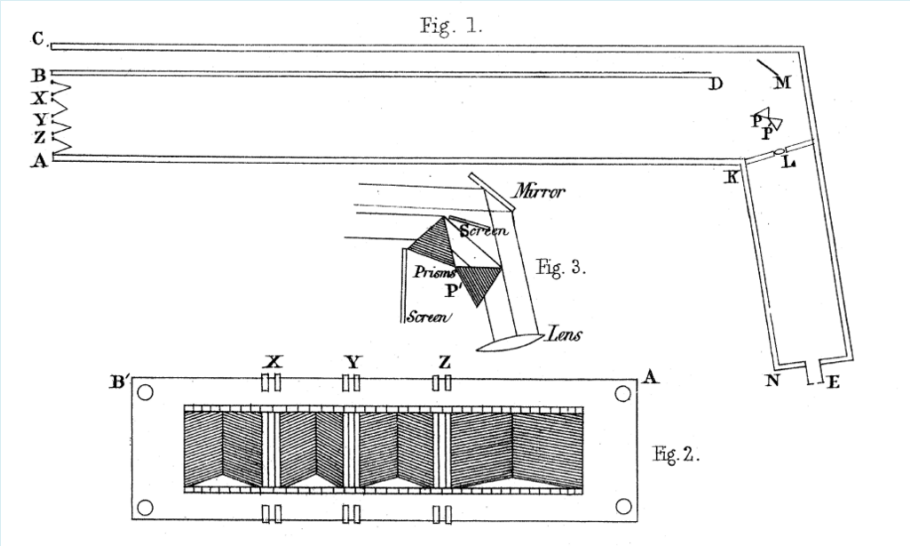

**John Kerr** (1824−1907) was a Scottish physicist and mathematician who made significant contributions to the field of optics. He is best known for his work on the **Kerr effect**, which describes the change in the refractive index of a material when it is placed in an electric field. **Kerr** was born in **Ardrossan**, Scotland, and studied at the University of Glasgow. He later became a professor of natural philosophy at the University of Glasgow, and later at the University of Edinburgh. In addition to his work on the **Kerr effect**, he also conducted research on polarization of light, the properties of crystals, and the electromagnetic theory of light. Kerr's most important contribution to science was the discovery of what is now known as the **Kerr effect**. In 1875, he observed that when a beam of light passed through a transparent material such as glass or quartz that was placed in an electric field, the refractive index of the material changed. This effect is now used in many applications, including optical communications, laser technology, and medical imaging. **Kerr** was a fellow of the **Royal Society of Edinburgh** and the **Royal Society of London**, and received numerous honors and awards for his work in optics and mathematics. He is remembered as a pioneer in the field of optics and a significant figure in the history of physics.



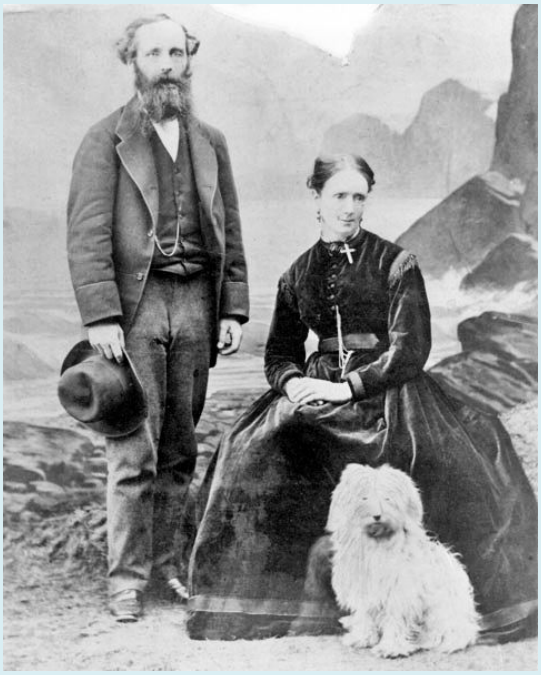


Townes (right) receiving the 1964 Nobel Prize

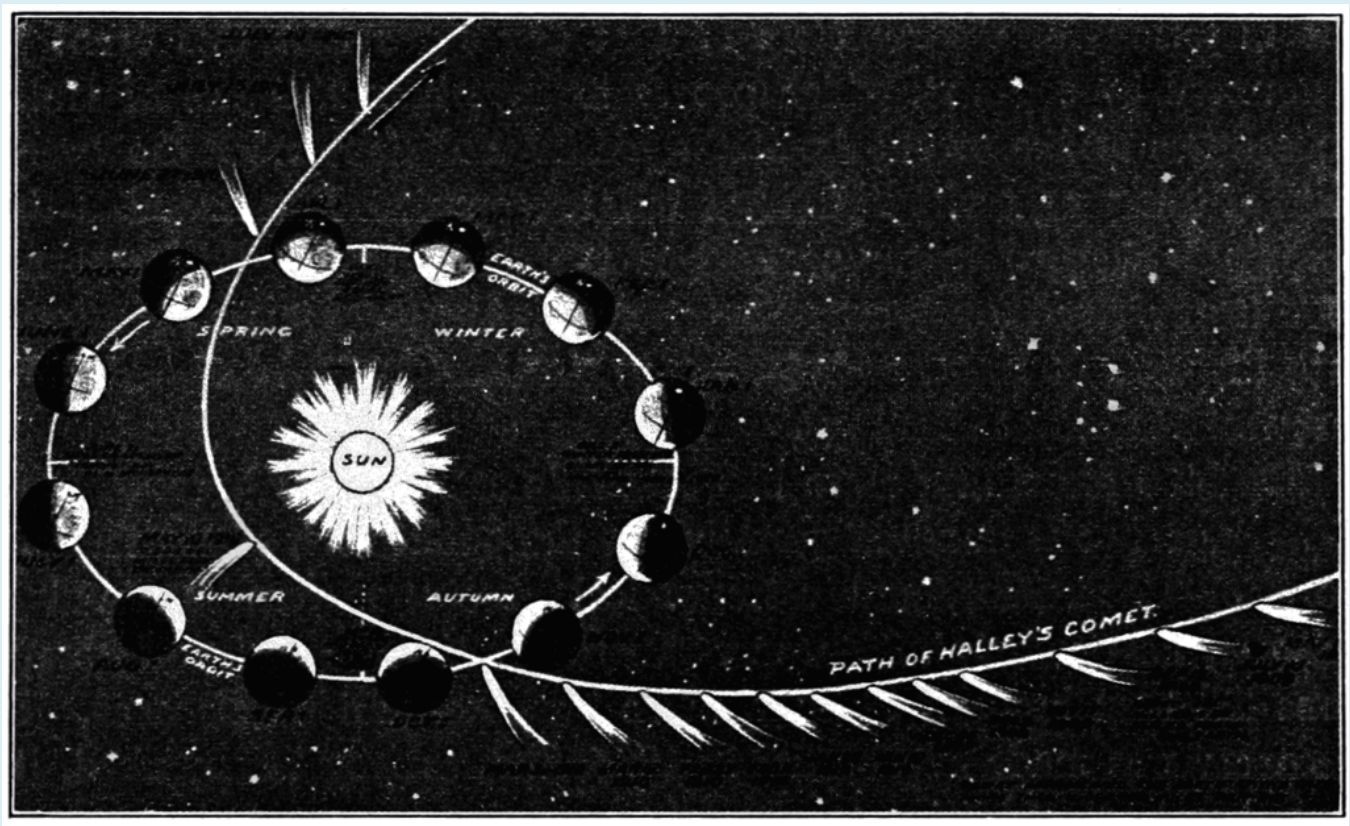
**Charles Hard Townes** (1915–2015) was an American physicist who made significant contributions to the **development of the laser and the field of microwave spectroscopy**. He was awarded the **Nobel Prize in Physics in 1964** for his work in developing the theory and design of the maser **(microwave amplification by stimulated emission of radiation)**. Townes was born in Greenville, South Carolina, and studied physics at Furman University and Duke University. He received his **Ph.D. in physics** from the California Institute of Technology in 1939. During **World War II**, he worked on radar research for the **U.S. Navy**, and later joined the faculty at Columbia University. In 1951, Townes began working on the development of the maser, which uses the same basic principles as the laser but at microwave frequencies. He and his colleagues built the first working maser in 1954, and later adapted the technology to create the laser, which operates at optical frequencies. **Townes** also made important contributions to the field of microwave spectroscopy, which uses microwaves to study the structure of molecules and atoms. In addition to his work in physics, **Townes** was also interested in the intersection of science and religion, and wrote a book on the subject called **"Making Waves: The Story of Radio Astronomy."** He received numerous awards and honors for his work in physics, including the **National Medal of Science** and the **Templeton Prize**. He is remembered as a pioneering figure in the field of quantum electronics and a leading voice in the dialogue between science and religion.




This is a diagram of the apparatus that **James and Katherine** used in their Colour Light experiments, as it was published in James Clerk Maxwell's January 1860 Philosophical Transactions article, "**On the Theory of Compound Colours, and the Relations of the Colours of the Spectrum,**" Vol. 150, pp. 57–84.



**A picture of Katherine Clerk Maxwell (sitting), James Clerk Maxwell, and Toby, the couple's dog.**




**1910 drawing of the path of Halley's Comet**

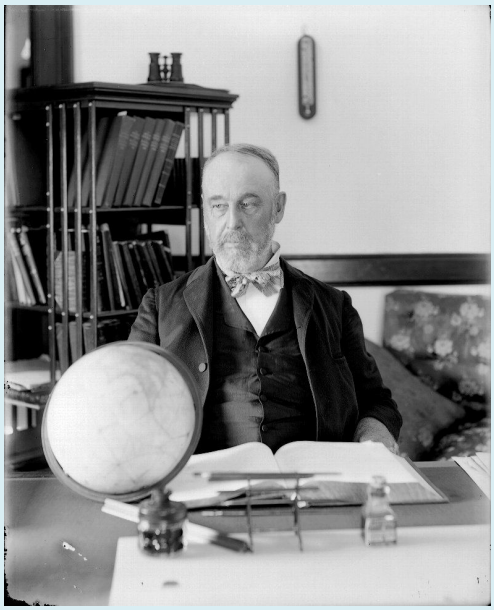


**A colorized image of the Martian moon "Deimos" taken on February 21st, 2009, by the HiRISE instrument located on the Mars Reconnaissance Orbiter.**



**A colorized image of the Martian moon "Phobos" taken on 23rd March 2008, by the HiRISE instrument located on the Mars Reconnaissance Orbiter.**

**High Resolution Imaging Science Experiment**



**Professor Asaph Hall**

(Best known for his discovery of the two moons of Mars, which he named **Phobos** and **Deimos**)



Asaph Hall's telescope, which he used for discovering the Martian moons

## Mars Trojan

A **Mars Trojan** is an asteroid that shares the orbit of Mars around the Sun, but stays either ahead of or behind Mars in a stable position known as a **Lagrange point**. There are currently nine known **Mars Trojans**, with the first discovered in 1990. These **Trojans** are believed to have originated in the outer asteroid belt and were captured by Mars' gravity. The study of **Mars Trojans** can provide insights into the early history of the solar system, as well as the formation and evolution of Mars itself.

The **Uncertainty Principle** is a fundamental principle in **quantum mechanics** that states that the more precisely the position of a particle is known, the less precisely its momentum can be known, and vice versa. Mathematically, the **uncertainty principle** is expressed as:

$$\Delta x \times \Delta p \geq \frac{\hbar}{2}$$

where:

- $\Delta x$ = uncertainty in the position of the particle
- $\Delta p$ = uncertainty in the momentum of the particle
- $\hbar$ = reduced Planck's constant, which is approximately equal to $1.054571726 \times 10^{-34}$ joule-seconds

Let's take an example to understand this principle better. Suppose we want to measure the position and momentum of an electron. We use a device to measure the position of the electron with an uncertainty of $10^{-9}$ meters. According to the uncertainty principle, the minimum uncertainty in the momentum of the electron is given by:

$$\Delta p \geq \frac{\hbar}{2\Delta x}$$

$$\Delta p \geq \frac{1.054571726 \times 10^{-34}\ \text{Js}}{2 \times 10^{-9}\text{m}}$$

$$\Delta p \geq 5.27285863 \times 10^{-26}\ \text{kg m/s}$$

This means that if we know the position of the electron with an uncertainty of **$10^{-9}$ meters**, the minimum uncertainty in its momentum is greater than or equal to **$5.27285863 \times 10^{-26}$ kg m/s.**

Similarly, if we want to measure the momentum of the electron with an uncertainty of $10^{-25}$ kg m/s, the minimum uncertainty in its position is given by:

$$\Delta x \geq \frac{\hbar}{2\Delta p}$$

$$\Delta x \geq \frac{1.054571726 \times 10^{-34}\ \text{Js}}{2 \times 10^{-25}\ \text{kgm/s}}$$

$$\Delta x \geq 5.27285863 \times 10^{-10}\ \text{m}$$

This means that if we know the momentum of the electron with an uncertainty of **$10^{-25}$ kg m/s**, the minimum uncertainty in its position is greater than or equal to **$5.27285863 \times 10^{-10}$ meters**. So, the **uncertainty principle** implies that there is always a trade-off between the precision with which we can measure the position and momentum of a particle. The more precisely we measure one quantity, the less precisely we can measure the other.



Werner Heisenberg



**Prof. Dr. Werner Heisenberg,**
der erst 32jährige Physiker an der Universität Leipzig, erhielt für seine Arbeiten auf dem Gebiet der Quantentheorie die Hälfte des Nobelpreises für Physik aus dem Jahre 1932

Phot. Max Löhrich

**Ohm's Law** states that the current flowing through a conductor between two points is directly proportional to the voltage across the two points, provided the temperature and other physical conditions remain constant. This can be expressed mathematically as:

$$V = I \times R$$

where:

- V is the voltage (measured in volts)
- I is the current (measured in amperes)
- R is the resistance (measured in ohms)

To give an example, let's say we have a circuit with a voltage of **12 volts** and a resistance of **4 ohms**. We can use **Ohm's Law** to calculate the current flowing through the circuit:

$$I = \frac{V}{R} = \frac{12 \text{ volts}}{4 \text{ ohms}} = 3 \text{ amperes}$$

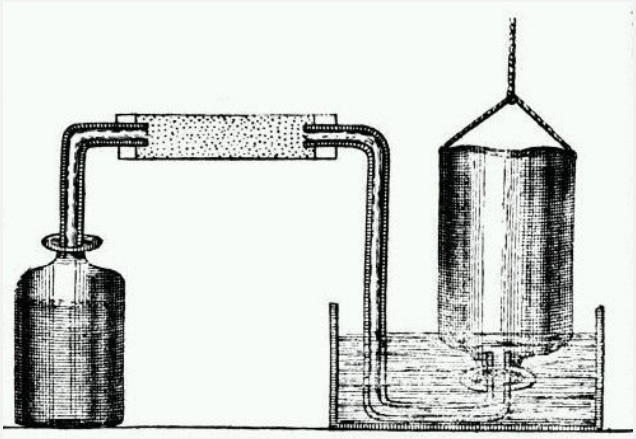
So the current flowing through the circuit is 3 amperes. Conversely, we can also use **Ohm's Law** to calculate the resistance of a circuit, given the voltage and current:

$$R = \frac{V}{I} = \frac{12 \text{ volts}}{3 \text{ amperes}} = 4 \text{ ohms}$$

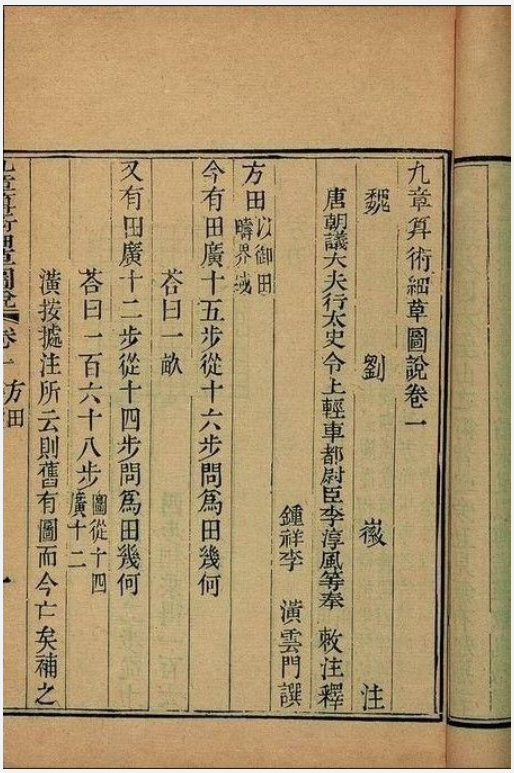
So the resistance of the circuit is 4 ohms.

**Henry Cavendish** (1731–1810) was an English scientist and polymath known for his contributions to chemistry, physics, and astronomy. He is best known for his discovery of hydrogen gas and for measuring the density of the Earth, which allowed for the first accurate determination of its mass. **Cavendish** was a shy and reclusive individual, often preferring to conduct his experiments in private. Despite this, he was a highly respected scientist during his lifetime and his work has had a lasting impact on our understanding of the natural world. He is considered to be one of the greatest experimentalists of all time.





**Cavendish's apparatus for making and collecting hydrogen**




A page of The **Nine Chapters on the Mathematical Art** (1820 edition)

This Chinese work, written in the 3rd century CE, includes many mathematical concepts that are relevant to physics, such as equations for calculating areas and volumes.

The **variation of mass with velocity** is an interesting concept in physics that is explored in the context of special relativity. It is commonly known as the **"relativistic mass"** and is defined as the mass of an object in motion relative to an observer. As an object moves faster, its relativistic mass increases, which can have significant consequences for the behaviour of the object. To understand this concept, it is important to first understand the **traditional concept of mass**. In **classical physics**, mass is considered to be an intrinsic property of an object that does not change with velocity. This means that the mass of an object is constant, regardless of how fast it is moving. However, in **special relativity**, this concept is modified. According to the theory of relativity, the mass of an object is not constant, but rather depends on its velocity. This concept is known as **relativistic mass**, and it is given by the equation:

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

where $m_0$ is the **rest mass of the object** (i.e. the mass of the object when it is at rest), v is the velocity of the object, and c is the speed of light. This equation shows that as the velocity of the object approaches the speed of light, its **relativistic mass** increases dramatically. At very high velocities, the relativistic mass can become infinite, making it impossible for the object to continue accelerating. **To illustrate this concept**, consider the following example. Let us assume that we have a **spaceship** that is traveling at a velocity of 0.9c **(where c is the speed of light)** relative to an observer on Earth. The spaceship has a rest mass of 1000 kg. Using the equation above, we can calculate the relativistic mass of the spaceship as follows:

$$m = \frac{1000\ \text{kg}}{\sqrt{1-\frac{(0.9c)^2}{c^2}}} \approx 2294.15733871\text{kg}$$

This means that the **relativistic mass** of the spaceship is almost 2.294 times its **rest mass**. As the **spaceship** continues to accelerate and approach the speed of light, its relativistic mass will continue to increase, making it more and more difficult to accelerate further. It is important to note that the concept of **relativistic mass** is somewhat controversial among physicists, and some argue that it is a misleading concept that can cause confusion and misunderstandings

about the fundamental nature of mass. Overall, the **variation of mass with velocity** is an important concept in physics that is explored in the context of **special relativity**. The concept of **relativistic mass** shows that as an object approaches the speed of light, its mass increases dramatically, which can have significant consequences for its behaviour. While the concept of **relativistic mass** is somewhat controversial, it is still an important concept to understand for anyone interested in the field of physics.



✓ Albert Einstein with his wife Elsa. War and Navy building in background. Washington, D.C.

**Length contraction** is a phenomenon predicted by the theory of special relativity, according to which the length of an object appears to be shorter when it is observed in motion relative to an observer. The amount of contraction depends on the relative velocity between the object and the observer, and can be calculated using the following formula:

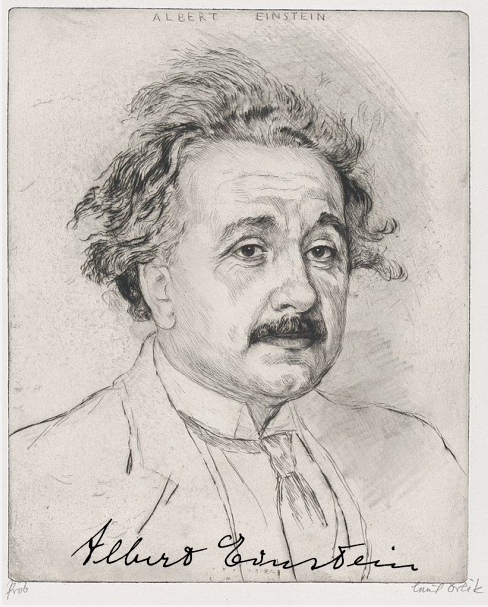
$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

where $L_0$ is the length of the object in the rest frame of the observer, L is the length of the object in the moving frame of the observer, v is the velocity of the moving observer and c is the speed of light. Let's take an example to understand this formula better. Suppose there is a rod that is at rest relative to an observer **A**. The length of the rod is measured as 10 meters by **A**. Now, suppose there is another observer **B** who is moving at a velocity of 0.6c **(60% of the**

**speed of light)** relative to **A**, in the same direction as the rod. According to the **length contraction formula**, the length of the rod measured by B would be:

$$L = 10\ m \sqrt{1 - \frac{(0.6c)^2}{c^2}} \approx 8\ m$$

So, even though the length of the rod is 10 meters for **A**, it appears to be shorter (8 meters) for **B** due to **length contraction**. This means that objects appear to be shorter in the direction of their motion relative to an observer who is at rest. This effect has also been experimentally confirmed in various experiments, including the **muon experiment**, where **muons** (subatomic particles) traveling at high velocities were found to have longer lifetimes due to **time dilation** and shorter lengths due to **length contraction**.




**Time dilation** is another phenomenon predicted by the theory of special relativity, according to which time appears to pass more slowly for objects in motion relative to an observer. The amount of **time dilation** depends on the relative velocity between the object and the observer, and can be calculated using the following formula:

$$\Delta t = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where $\Delta t_0$ is the time interval in the rest frame of the observer, $\Delta t$ is the time interval in the moving frame of the observer, and **v** is the velocity of the moving observer and c is the speed of light. Let's take an example to understand this formula better. Suppose there are **two observers**, A and B. **A** is at rest on Earth, and **B** is traveling in a spaceship at a velocity of 0.9c **(90% of the speed of light)** relative to **A**. Let's say **A** measures the time interval between two events as 10 seconds. According to the **time dilation** formula, the time interval measured by **B** would be:

$$\Delta t = \frac{10 \text{ seconds}}{\sqrt{1 - \frac{(0.9c)^2}{c^2}}} \approx 22.9415733871 \text{ seconds}$$

So, even though the time interval between the events is 10 seconds for **A**, it appears to be longer **(22.94 seconds)** for **B** due to **time dilation**. This means that time appears to move slower for **B**, who is moving relative to **A**. This effect has been experimentally confirmed in various experiments, including the famous **Hafele-Keating experiment**, where atomic clocks were flown around the world in opposite directions, and their readings were compared to clocks that remained on the ground. The experiment confirmed that time dilation occurs due to the motion of the clocks relative to each other.




✓ Einstein at a picnic near Oslofjorden in connection with his visit to Norway, June 1920



**Annie Jump Cannon** was indeed a prominent American astronomer who made significant contributions to the field of astronomy, particularly in the area of stellar classification. She was born on December 11, 1863, in Dover, Delaware, and passed away on April 13, 1941. Cannon's work on stellar spectra and classification revolutionized the field of astronomy and laid the foundation for our understanding of **stellar evolution**. She played a vital role in the development of the **Harvard Classification Scheme**, also known as the **Harvard Spectral Classification**, which became the standard system for classifying stars. Working at the Harvard College Observatory, **Cannon** developed a method to classify stars based on their spectral lines. She meticulously examined thousands of **stellar spectra**, carefully cataloging and organizing them. Her classification system sorted stars into different spectral types based on the strengths and patterns of spectral lines present in their light. Cannon's work resulted in the development of a simplified **stellar classification system** using the letters O, B, A, F, G, K, and M to represent different spectral types. This system, known as the Harvard Spectral Classification, is still widely used today, with additional refinements and expansions. In recognition of her significant contributions, **Cannon** became the first woman to receive an **honorary doctorate** from **Oxford University** in 1925. She was also the first woman to become an officer of the **American Astronomical Society** and later served as its president. Annie Jump Cannon's work on stellar classification and her dedication to astronomy played a crucial role in advancing our understanding of the universe and paved the way for future astronomical research. Her contributions continue to be celebrated and appreciated in the field of astronomy.



Annie Jump Cannon at her desk at the Harvard College Observatory

**Luminosity of the star = Energy flux of the star × Surface area of the star**

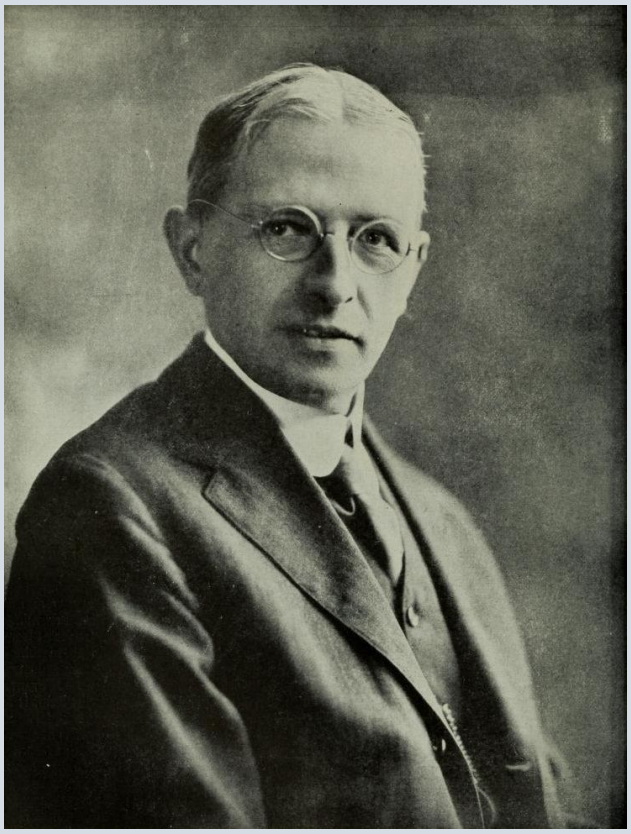
Suppose we have a star with an energy flux (F) of $5 \times 10^6$ W/m² and a surface area (A) of $2 \times 10^{10}$ m². We can calculate the luminosity (L) of the star using the equation:

$$L = F \times A$$

$$L = (5 \times 10^6 \text{ W/m}^2) \times (2 \times 10^{10} \text{ m}^2)$$

$$L = 10^{17} \text{ W}$$

In this example, the star has a luminosity of $10^{17}$ watts. Our Sun has a luminosity of about $3.828 \times 10^{26}$ watts, making it a relatively average star in terms of luminosity. So a star with a luminosity of $10^{17}$ watts would be much less luminous than our Sun.



**Henry Norris Russell** was an American astronomer who made significant contributions to the field of stellar evolution. He is best known for his collaboration with Danish astronomer **Ejnar Hertzsprung** in developing the **Hertzsprung–Russell diagram** (H-R diagram) in the early 20th century.



**Karl Schwarzschild** and **Ejnar Hertzsprung** (right) in front of the Göttingen Observatory building in 1909.

## Newton's Second Law of Motion

**Newton's Second Law of Motion** states that the net force acting on an object is directly proportional to its acceleration, and inversely proportional to its mass. Mathematically, this can be expressed as:

$$F = m \times a$$

where F is the net force acting on an object, m is its mass, and a is its acceleration. Let's consider an example to illustrate this law. Suppose a 5 kg object is acted upon by a net force of 10 N.

### ✓ What is its acceleration?

Using Newton's Second Law, we can solve for the acceleration as follows:

$$F = m \times a$$

$$10\ \text{N} = 5\ \text{kg} \times a$$

$$a = \frac{10\ \text{N}}{5\ \text{kg}} = 2\ \text{m/s}^2$$

Therefore, the **acceleration** of the object is **2 m/s²**. This equation tells us that the force required to accelerate an object is directly proportional to its mass. For example, to accelerate a **10** kg object at the same rate as the **5 kg** object, we would need to apply twice as much force (**20 N**) since its mass is twice as much. Similarly, to achieve the same acceleration with a heavier object (e.g. **20 kg**), we would need to apply a proportionally larger force.



**Lucy Hawking** is an English author, journalist, and educator. She was born on November 2, 1970, in London, England, and is the daughter of renowned physicist Stephen Hawking and his first wife, Jane Wilde Hawking. She has two brothers, **Robert and Timothy Hawking**. **Lucy Hawking** is known for her work in popularizing science and making it accessible to a wider audience, particularly young people. She has written several books for children and young adults, including the **"George"** series, which she co-wrote with her father. The books follow the adventures of a boy named **George** and his friend **Annie**, as they travel through space and time and learn about scientific concepts such as black holes, relativity, and the big bang. Hawking has also worked as a journalist, writing for publications such as the Daily Mail, The Telegraph, and New York Magazine. She has appeared on numerous television programs, including **"The Sky at Night"** and **"Stephen Hawking's Universe"**, and has given talks and presentations at schools and universities around the world. In addition to her work in science communication, **Lucy Hawking** is also an advocate for disability rights and has spoken about her own experiences growing up with a disabled father. She has been awarded several honors for her work, including an honorary degree from the University of Portsmouth and the **Sappho Prize** from the Women's Literature Festival in Italy.



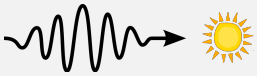
**Classical Thermodynamics** is the study of the macroscopic behavior of thermodynamic systems, primarily focusing on the relationships between thermodynamic variables such as temperature, pressure, and volume. **Classical thermodynamics** deals with the principles and laws governing energy and its transformations, as well as the behavior of matter in relation to heat and work.



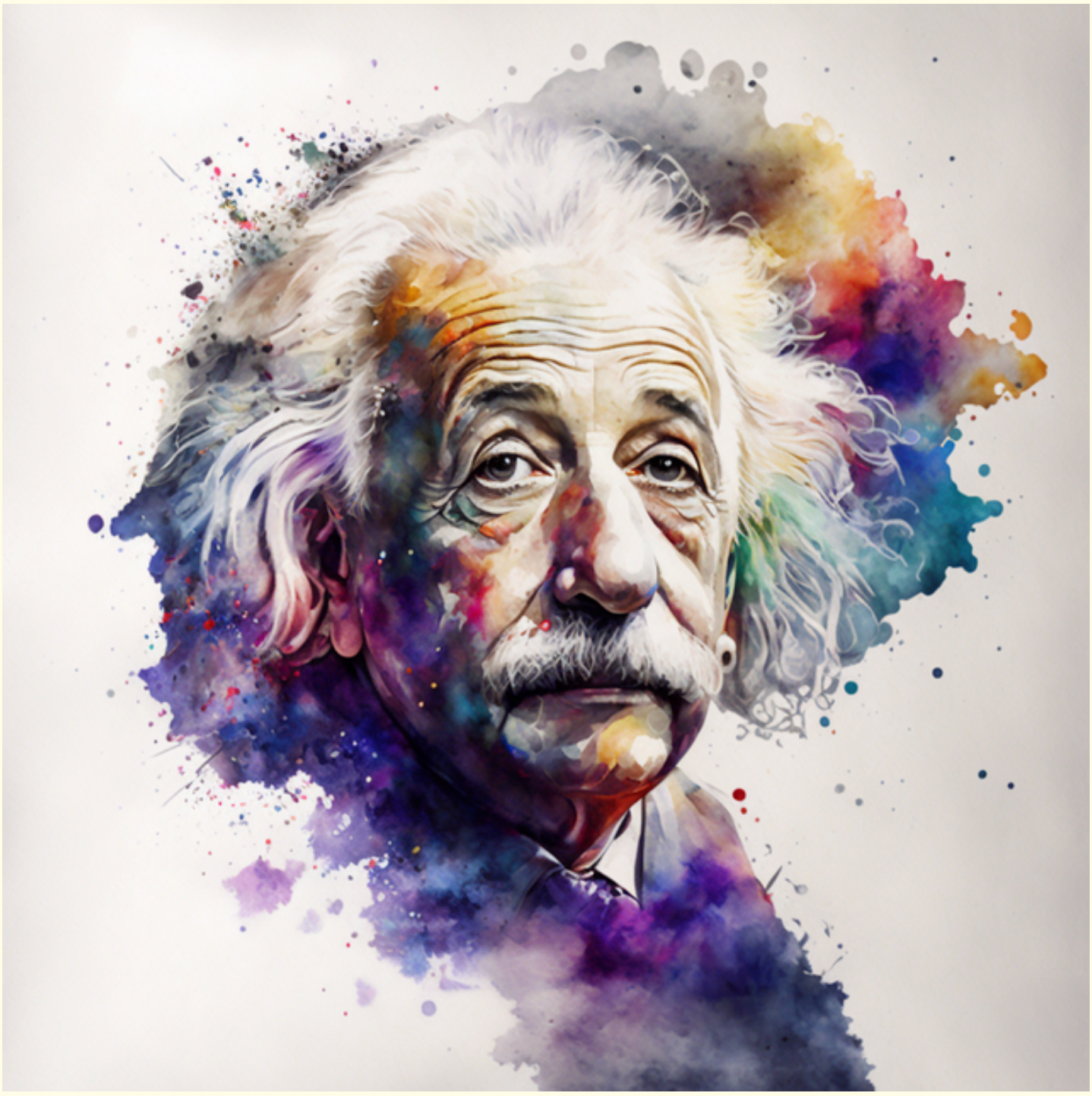
**Statistical Thermodynamics**, also known as statistical mechanics, is a branch of physics that seeks to explain the behavior of a macroscopic system through the behavior of its microscopic constituents, such as atoms and molecules. It uses statistical methods to analyze the behavior of these particles and their interactions with one another. **Statistical thermodynamics** provides a theoretical foundation for understanding macroscopic thermodynamic properties such as temperature, pressure, and entropy.



**Chemical Thermodynamics** is the branch of thermodynamics that deals with the study of the energy changes and transformations that occur during chemical reactions. It involves the application of thermodynamic principles to chemical systems, including the determination of reaction enthalpies, free energies, and entropy changes. **Chemical thermodynamics** is used extensively in the study of chemical reactions and in the design and optimization of chemical processes.



**Equilibrium Thermodynamics** deals with the thermodynamic properties of systems that are in thermodynamic equilibrium. It is concerned with the study of the behavior of systems that are in a steady state, where there are no net flows of energy or matter between the system and its surroundings. **Equilibrium thermodynamics** provides a theoretical foundation for understanding the behavior of thermodynamic systems under conditions of constant temperature, pressure, and other thermodynamic variables.



Albert Einstein

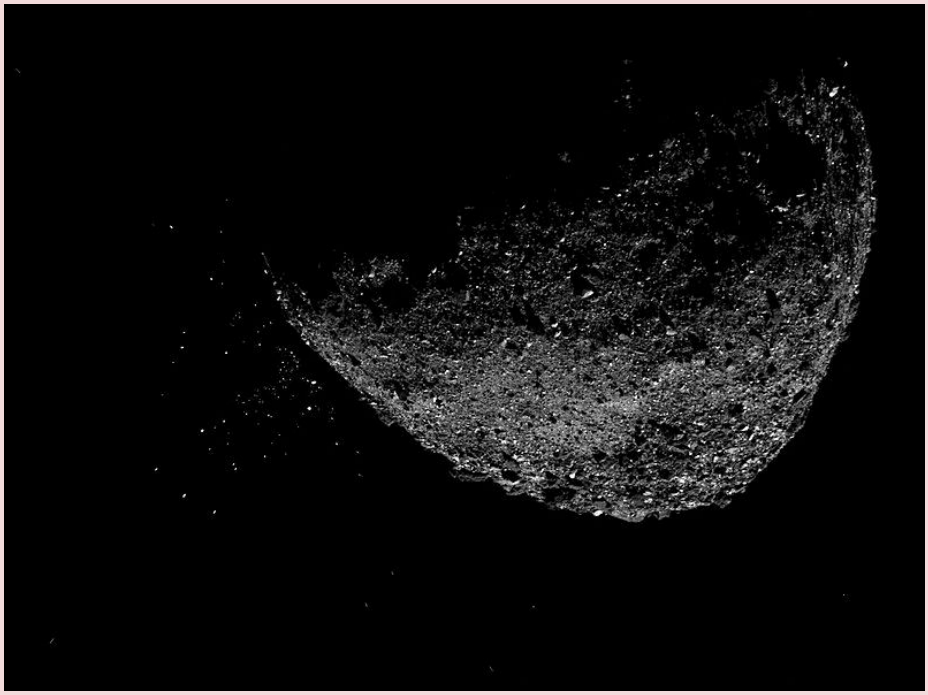
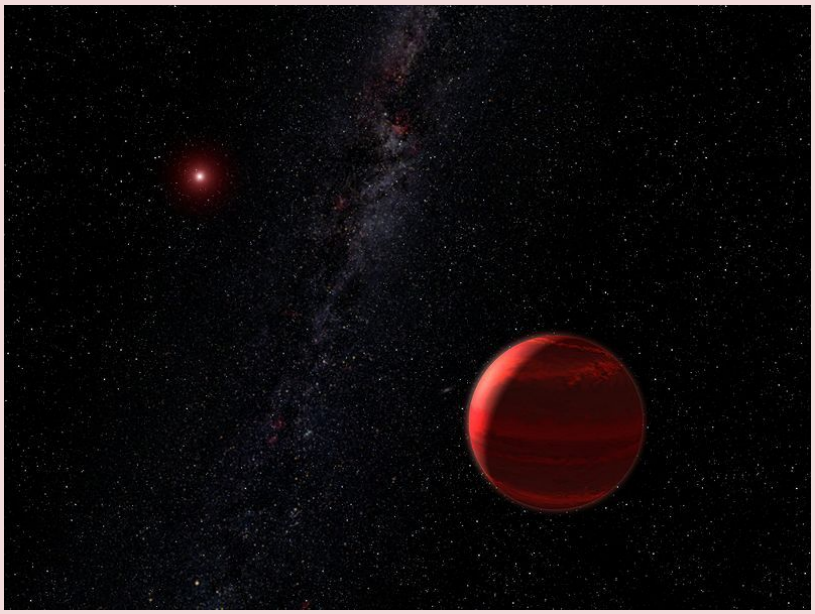
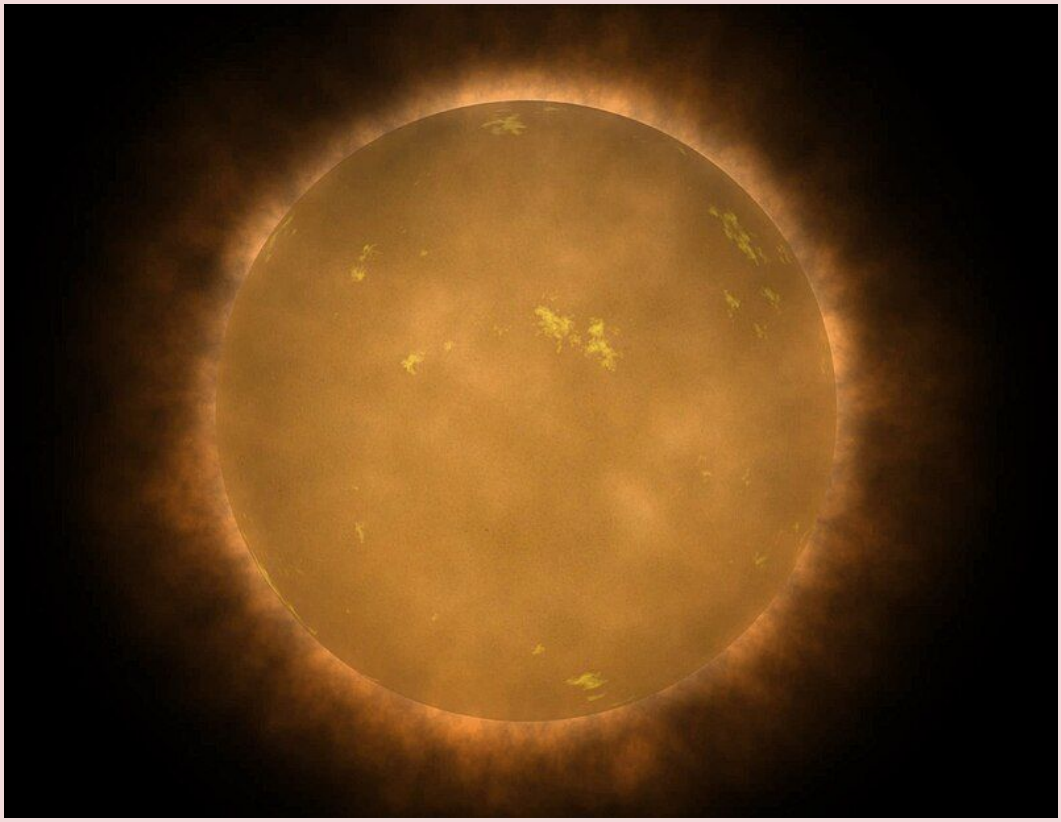


**Image captured by the OSIRIS-REx probe on January 6, 2019, show the asteroid 101955 Bennu ejecting particles.**



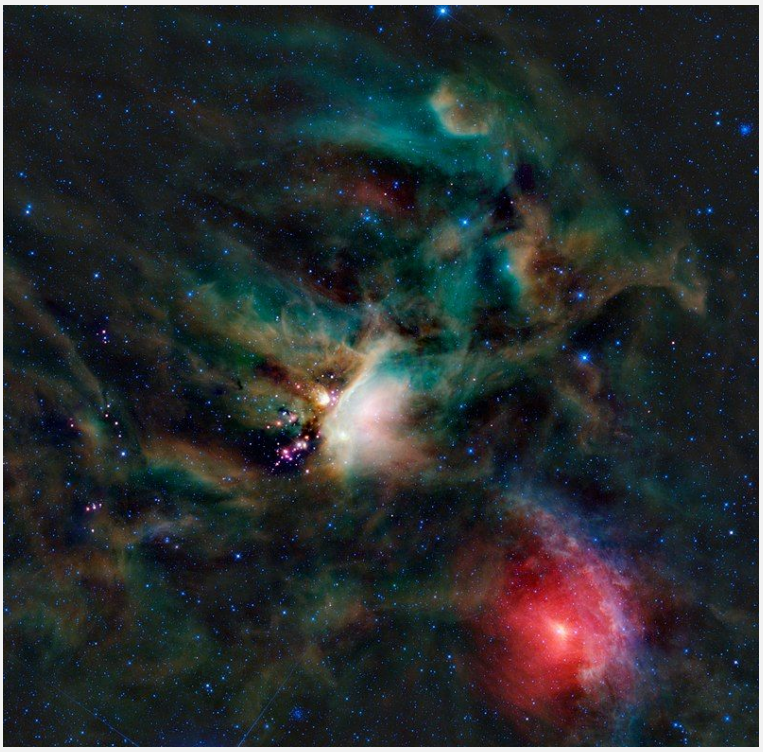
**Conception of a planet in orbit around a red dwarf by an artist**



**Red dwarf star SO25300.5+165258, which is about 7.8 light years from the sun, as it is depicted in an artist's conception.**

## Tyche

**Tyche** is a hypothetical gas giant planet that some scientists have proposed to exist in the outermost regions of the solar system. The existence of **Tyche** has been suggested to explain some peculiarities observed in the orbits of some distant objects beyond Neptune, known as the "extended scattered disk". According to the hypothesis, **Tyche** would be a massive planet, up to four times the size of Jupiter, orbiting the Sun at a distance of up to 15,000 astronomical units (AU). However, no direct evidence of **Tyche's existence** has been found, and its existence remains a topic of debate in the scientific community.



✓ **The ρ Oph cloud complex**

(A star-forming region in the Gould Belt)

The **Gould Belt** is a ring-shaped region of the **Milky Way galaxy** that contains many young, bright stars. It is a large, star-forming region that stretches across a distance of approximately 3,000 light-years and is tilted at an angle of about 20 degrees relative to the plane of the galaxy. The belt contains several well-known star clusters, including the Pleiades and the Orion Nebula Cluster, and is named after the American astronomer **Benjamin Apthorp Gould** in recognition of his contributions to the study of the structure and dynamics of the Milky Way. The **Gould Belt** is thought to be the result of a series of star-forming events that occurred over the past few hundred million years.






The locations of the star systems nearest to the sun are depicted in this image.

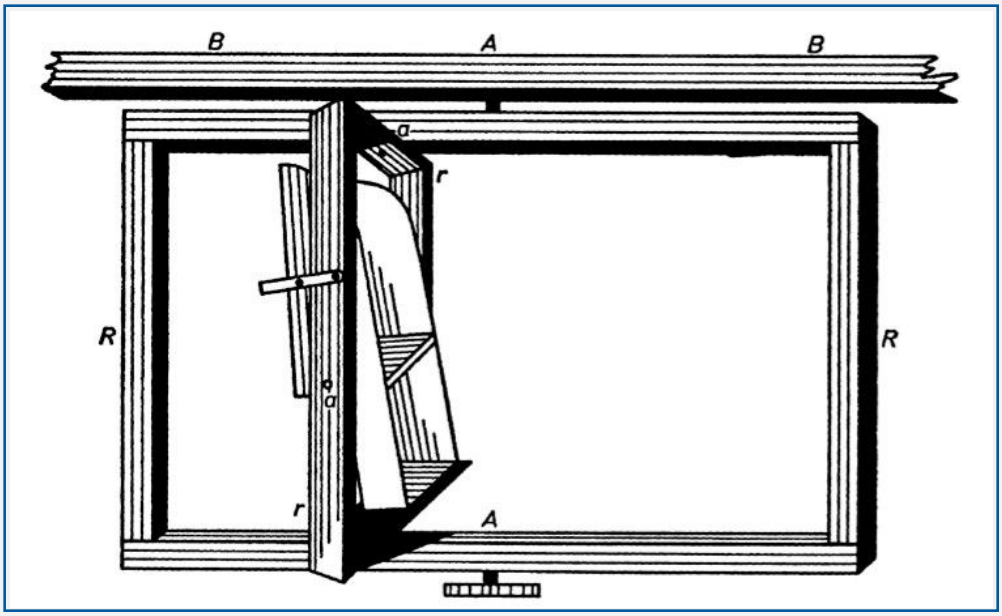




Dr Ernst Mach

**Ernst Mach** (1838–1916) was an Austrian physicist and philosopher. He made significant contributions to the fields of mechanics, optics, and psychology. Mach's work in mechanics is particularly notable for his development of the concept of **Mach's principle**, which suggests that the inertia of a body is influenced by the presence of other matter in the universe. He also formulated the principle of energy conservation in mechanics. In optics, **Mach** conducted experiments on the perception of motion and developed the **"Mach bands"** phenomenon, which describes the visual perception of bands of brightness that appear near the edges of objects. **Mach** was also interested in psychology and wrote extensively on the topic. He believed that the mind was a product of the brain's physical processes and that knowledge was a result of the interaction between the individual and the environment. **Mach's ideas** had a significant impact on the development of modern physics and philosophy, and his work continues to be studied and discussed today.






**Spinning chair designed by Ernst Mach to examine the experience of motion**

**Nucleocosmochronology**

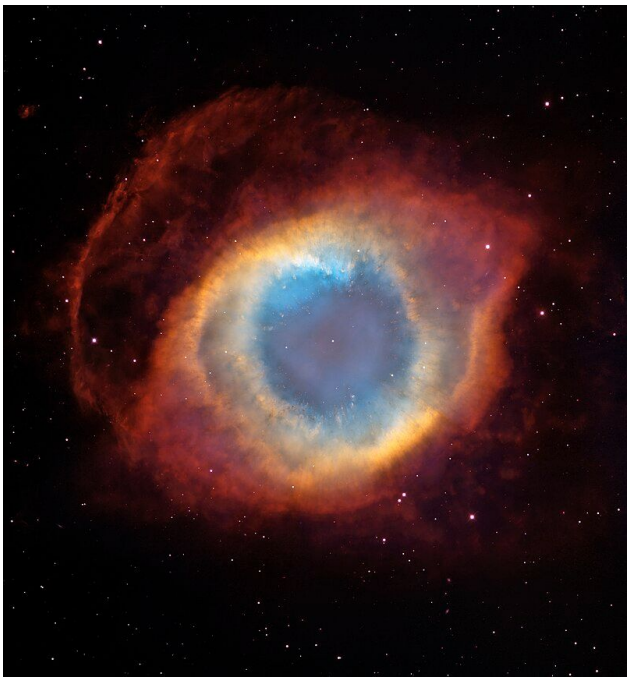
Nucleocosmochronology is a scientific method that uses the radioactive decay of certain isotopes to determine the age of the universe. It combines knowledge from nuclear physics, cosmology, and astrophysics to estimate the age of the oldest known objects in the universe, such as stars, globular clusters, and galaxies. The method relies on measuring the abundance of certain radioactive isotopes and their decay products in these objects. By comparing these measurements to theoretical models of nucleosynthesis and stellar evolution, scientists can estimate the time elapsed since the objects formed. One of the key isotopes used in nucleocosmochronology is **uranium-238**, which has a half-life of 4.5 billion years. By measuring the ratio of uranium-238 to its decay product lead-206 in ancient rocks, scientists can estimate the age of the Earth and the Solar System. Nucleocosmochronology is an important tool for understanding the history and evolution of the universe. It has helped scientists to estimate the age of the universe to be around 13.8 billion years, and to investigate the processes that have shaped the cosmos over its history.



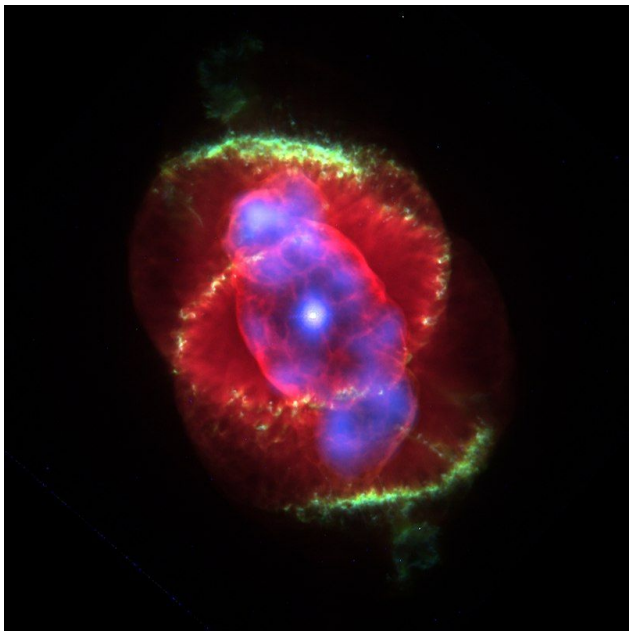
**When viewed from space on board the International Space Station at an altitude of 335 km (208 mi), blue light is scattered more than other wavelengths by the gases in the atmosphere, surrounding Earth in a clearly visible blue layer at the stratosphere above the clouds of the troposphere (the Moon is visible as a crescent in the distant background).**

## ✓ Planetary nebulae

When a star like our Sun, reaches the end of its life, it undergoes a process that differs from exploding into a supernova or collapsing into a black hole. Instead, it gracefully sheds its outer layers, creating an exquisite cloud known as a **"planetary nebula."** Meanwhile, the core of the dying star transforms into a dense remnant called a **white dwarf**.

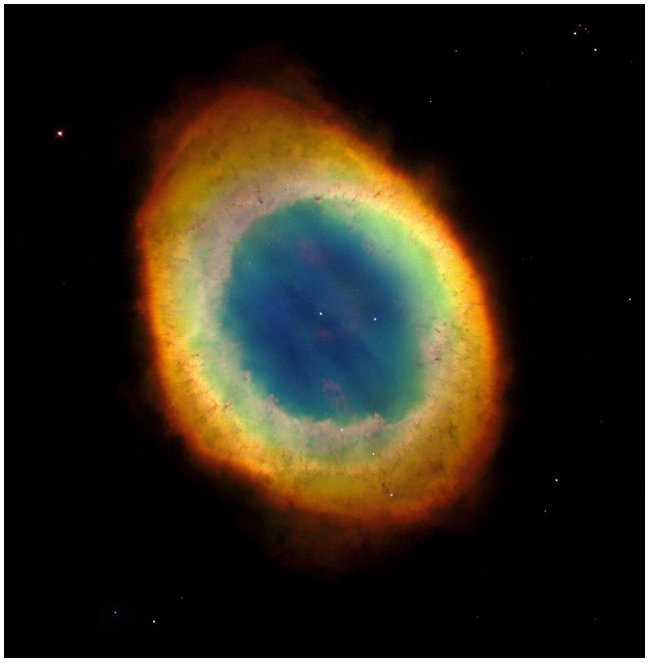


☼ **NGC 7293**, the Helix Nebula

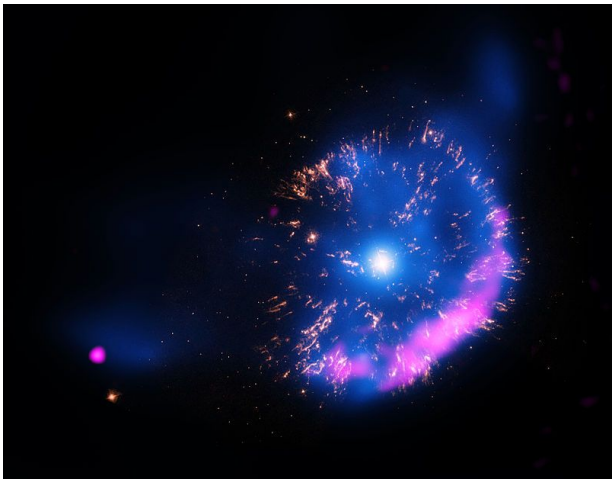


☼ **NGC 6543**, the Cat's Eye Nebula

Brown dwarfs are celestial objects that are too small to sustain nuclear fusion reactions in their cores, which is the energy source that powers stars. They are intermediate in mass between the heaviest gas giants and the lightest stars, with a mass range of about 13 to 80 times that of Jupiter. Brown dwarfs have low luminosities and surface temperatures, and they emit most of their light in the infrared part of the spectrum. Due to their faintness, they are difficult to detect and study, but they are thought to be abundant in our Milky Way galaxy.



**NGC 6720,** the Ring Nebula

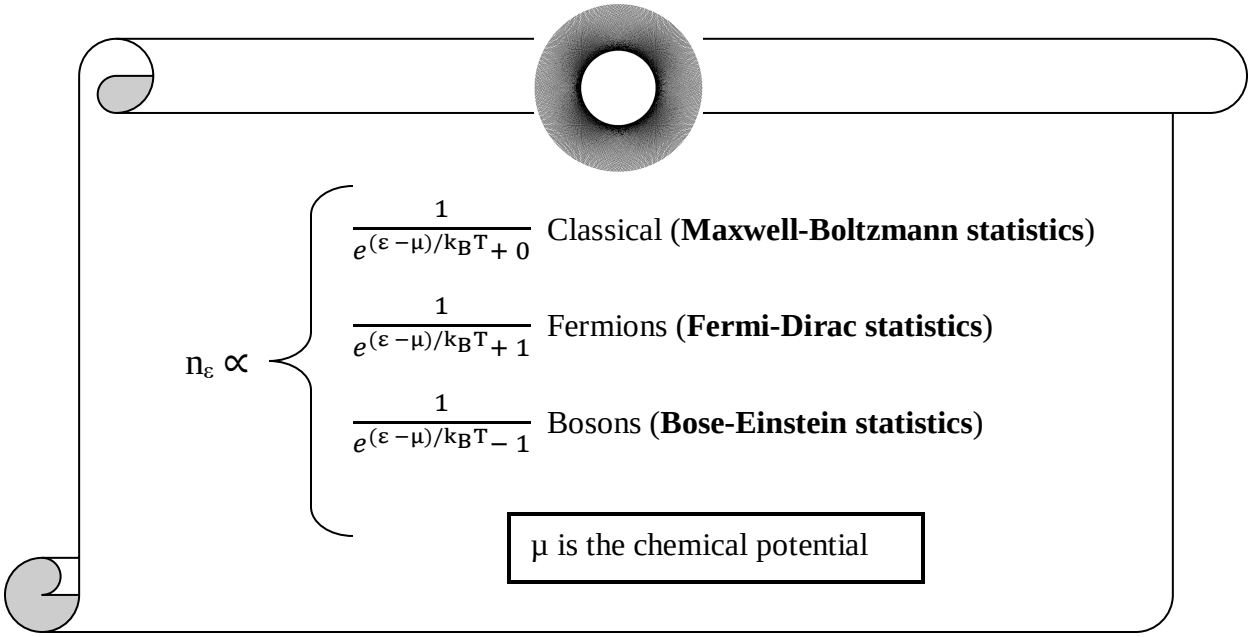


**GK Persei**, also known as **Nova Persei 1901**, is an outburst produced by a thermonuclear explosion on the surface of a white dwarf star.



The **Large Magellanic Cloud**, a satellite galaxy of the Milky Way

| | |
|---|---|
| **Outgassing** | The release of gases from a planet's interior |
| **Planetesimals** | Small bodies that are formed from the solar nebula and eventually grew into protoplanets |
| **Precession** | The slow change in the direction of Earth's axis of rotation |




| | |
|---|---|
| **Pulsar wind** | The flow of high-energy particles that carries most of the energy away from a spinning neutron star |
| **Roche limit** | If a satellite's orbit brings it within its planet's **Roche limit**, tidal forces will pull the satellite apart. |
| **Roche lobe** | In a system with two bodies orbiting each other, the volume of space dominated by the gravitation of one of the bodies |
| **Roche surface** | In a system with two bodies orbiting each other, the outer boundary of the volume of space dominated by the gravitation of one of the bodies |

## ✓ Self-sustaining star formation

The process by which the birth of stars compresses the neighboring clouds of gas and triggers the formation of more stars

## Spectral sequence

**High to low temperature sequence**

The arrangement of spectral classes (**O, B, A, F, G, K, M**) ranging from hot to Cool. O class stars are high temperature stars and M class stars are low temperature stars.

- **Spectrum** is an arrangement of electromagnetic radiation in order of wavelength = $\frac{\text{speed of light}}{\text{frequency}}$

**THE UNIVERSE IS NOT MADE OF ATOMS.**

**IT IS MADE OF TINY STORIES.**



| | |
|---|---|
| **sunspot** | Dark spot on the sun that contains intense magnetic fields |
| **supernova (type I)** | The violent explosion of a star in which the spectrum contains no hydrogen lines |
| **supernova (type Ia)** | The explosion of a star caused by the collapse of a white dwarf that has gained mass from its binary companion and exceeds the Chandrasekhar limit |
| **supernova (type Ib)** | The explosion of a massive star that develops an iron core and collapses after it has lost its outer layers of hydrogen |
| **supernova (type II)** | The explosion of a massive star that develops an iron core and collapses |
| **tidal heating** | The heating of a planet or satellite because of friction caused by tides |
| **transition** | The movement of an electron from one atomic orbit to another |
| **21-cm radiation** | Radio emission produced by cold, low-density hydrogen in interstellar space |
| **triple alpha process** | The nuclear fusion process that combines three helium nuclei (alpha particles) to make one carbon nucleus. |
| **Y dwarf** | A spectral class of brown dwarf with temperature below 500 K |

## ✓ Chandrasekhar mass limit:

$$M_{limit} = \frac{\omega_3^0\sqrt{3\pi}}{2} \times \frac{1}{\mu_e} \times \frac{(\text{Planck mass})^3}{(\text{proton mass})^2}$$

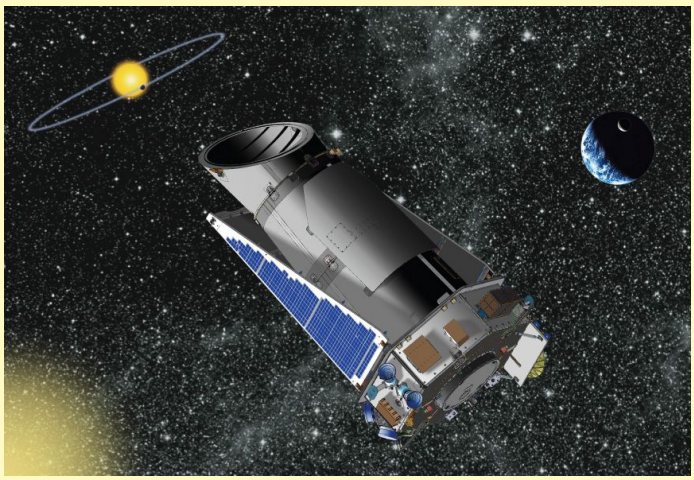
- $\mu_e$ is the average molecular weight per electron, which depends upon the chemical composition of the star.
- $\omega^0{}_3 \approx 2.018236$ is a constant connected with the solution to the **Lane–Emden** equation.

**Maximum mass of a stable white dwarf star**

A 1.4 $M_{sun}$ neutron star would consist of

$$\frac{1.4M_{sun}}{m_{neutron}} \approx 10^{57} \text{ neutrons}$$

- If $M_{star} = M_{limit}$: the speed of electrons is comparable to the speed of light, and thus relativity plays an essential role.

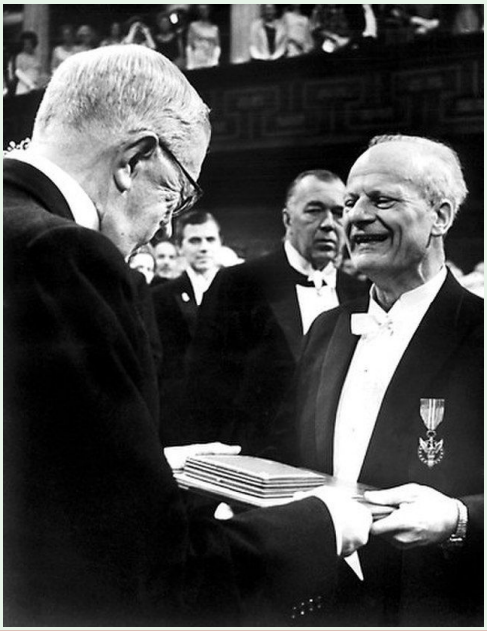


**Kepler, the first NASA project to look for possibly hospitable Earth-size planets, launched in March 2009.**

"Three principles – the conformability of nature to herself, the applicability of the criterion of simplicity, and the "unreasonable effectiveness" of certain parts of mathematics in describing physical reality – are thus consequences of the underlying law of the elementary particles and their interactions. Those three principles need not be assumed as separate metaphysical postulates. Instead, they are emergent properties of the fundamental laws of physics."



**– Murray Gell-Mann**



**Hans Bethe receiving his Nobel Prize from His Majesty the King Gustaf VI Adolf of Sweden at the Stockholm Concert Hall, 10 December 1967.**

"I have sometimes wondered whether a brain like von Neumann's does not indicate a species superior to that of man."

**– Hans Bethe**

✓ The gravitational force, $\mathbf{F_G}$, between two equal masses (each mass is denoted by **M**) separated by a distance r is given by:

$$\mathbf{F_G} = \frac{GM^2}{r^2}$$

If $\mathbf{F_G} = \frac{c^4}{4G} = \frac{\text{Planck Force}}{4}$:

$$\frac{c^4}{4G} = \frac{GM^2}{r^2}$$

$$r = \frac{2GM}{c^2}$$

Schwarzschild radius of the mass **M**



**Carl Friedrich Gauss**

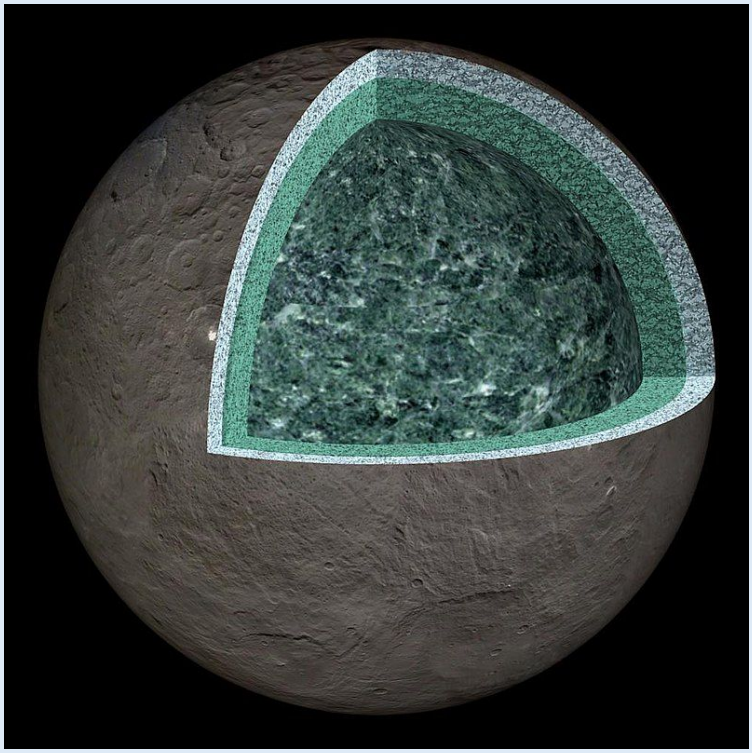
The Schwarzschild radius of the mass **M** is the distance of separation between two equal masses (each mass is denoted by **M**) if the gravitational force between two equal masses is equal to $\frac{1}{4}^{\text{th}}$ Planck force.

## Gauss's law for gravity

The total gravitational flux "$\Phi_G$" through a closed surface surrounding a mass "**M**" is proportional to the mass "**M**" enclosed within that surface

$$\Phi_G = -4\pi GM$$

The total gravitational flux "$\Phi_G$" through a closed surface surrounding a mass "**M**" is negative, indicating that the gravitational field is attractive towards the mass "**M**".

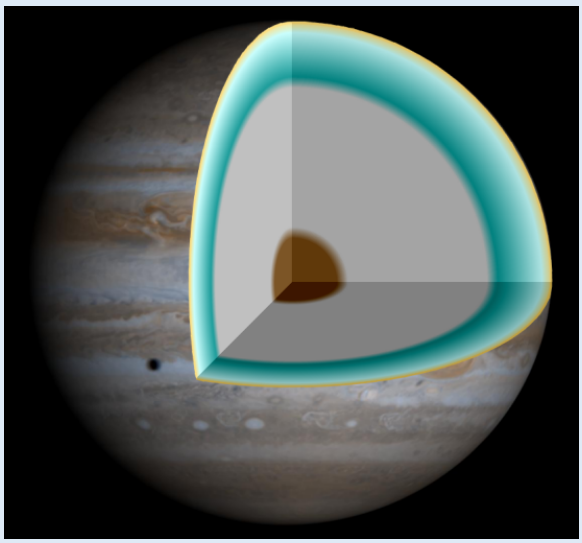


**Ceres**, the dwarf planet located in the asteroid belt, is believed to possess a **three-layer internal structure**. Its outermost layer consists of a **thick crust** composed of ice, salts, and hydrated minerals. Beneath the crust lies a layer of salt-rich liquid known as a **brine**. The **planet's innermost layer** is a "mantle" composed of hydrated rock. This **three-layer model** provides insights into **Ceres's composition** and the distribution of different materials within its structure.

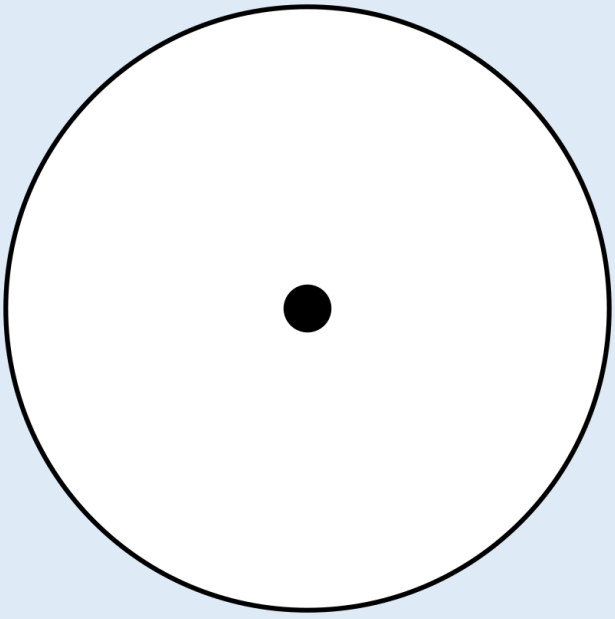
**Antimatter comets**

**Antimatter meteoroids**

Composed entirely of **antimatter** rather than ordinary matter, are hypothetical entities that have been proposed but never observed in the Milky Way or elsewhere. While the likelihood of their existence is considered low, scientists have put forward the idea as a theoretical possibility and explored it as a potential explanation for certain observed natural phenomena.



✓ Artistic depiction of the interior of **Jupiter**, with a rocky core overlaid by a deep layer of metallic hydrogen.



The **Pythagoreans** and later **ancient Greeks** utilized the **circled dot** as a symbol to represent the first metaphysical being known as the **Monad** or **The Absolute**. This symbol held significant philosophical and metaphysical importance in their cosmological and mathematical beliefs.

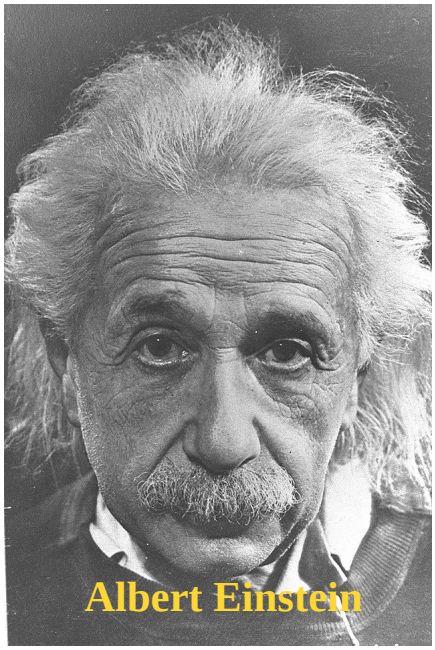


**Émilie du Châtelet** was a prominent French natural philosopher and mathematician during the early 1730s. One of her most notable accomplishments was her translation of and commentary on **Isaac Newton's** seminal work, **"Philosophiæ Naturalis Principia Mathematica,"** which contains the fundamental laws of physics. This translation, published posthumously in 1756, remains the standard and widely recognized **French translation of Newton's masterpiece**.

## ✓ Einstein's relativistic law:

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$m^2 (c^2 - v^2) = m_0^2 c^2$$



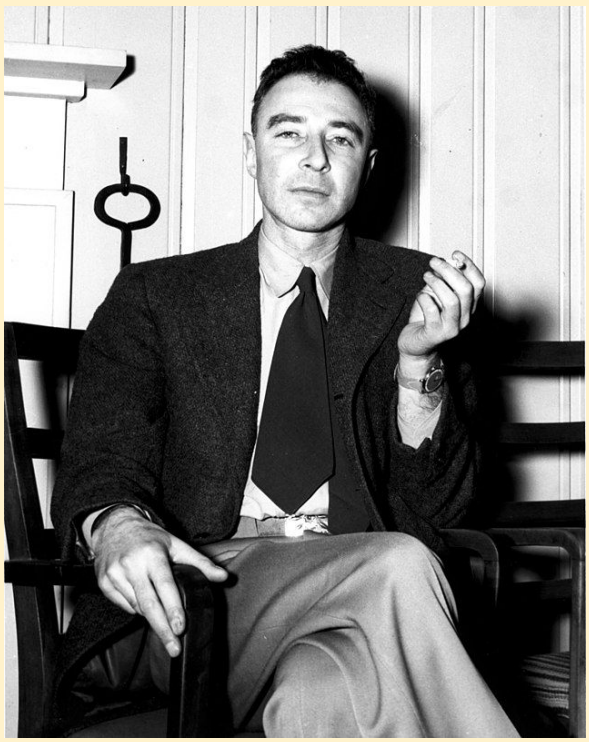

If m → Planck mass $= \sqrt{\frac{\hbar c}{G}}$:

$$(c^2 - v^2) = \frac{G m_0^2 c}{\hbar}$$

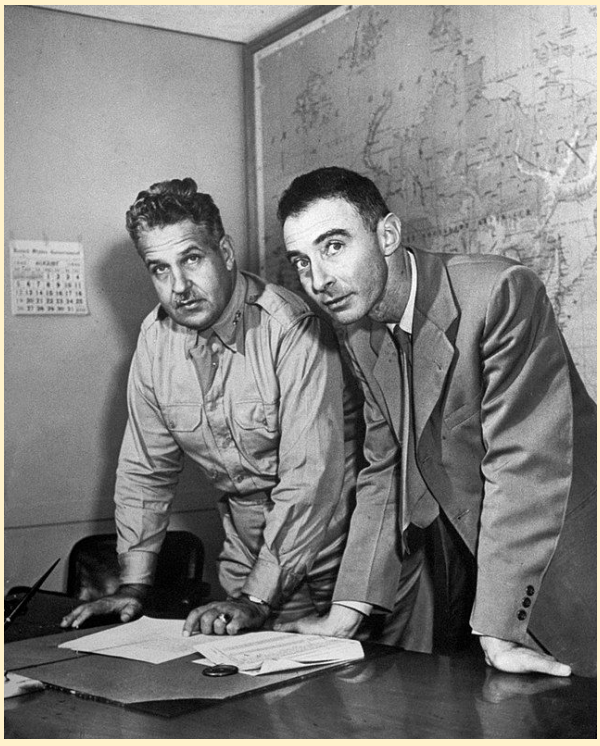
$$v = c\sqrt{1 - \frac{r_S}{2\lambda\!\!\!^{-}_C}}$$

- $r_S$ → Schwarzschild radius of the particle
- $\lambda\!\!\!^{-}_C$ → reduced Compton wavelength of the particle
- v → velocity a particle must travel so that its relativistic mass to be equal to **Planck mass**

**Quantum entanglement** → transmission of information between two particles or objects at infinite speed (or, at least, faster than the speed of light)



**J. Robert Oppenheimer** at the Guest Lodge, Oak Ridge, in 1946



**Leslie Groves** (left), military head of the Manhattan Project, with Professor **Robert Oppenheimer** (right)

A **black hole** of mass M cannot capture radiation with wavelength >> $\frac{2GM}{c^2}$. It follows that particle (real or virtual) with sufficiently small energies E ≪ $\frac{\hbar c^3}{8\pi GM}$ might avoid falling into the black hole horizon.



The **graviton's Compton wavelength** is $1.6\times10^{16}$ m, or about 1.6 light-years, corresponding to a graviton mass of no more than $7.7\times10^{-23}$ eV/$c^2$.

- Leptons and quarks carry weak charge.
- Color charge is only carried by quarks (not by leptons).
- Proton mass = 1836.149 × electron mass
- Neutron mass = 1838.679 × electron mass
- The de-Broglie wave-length λ of a particle with momentum p is given by:

$$\lambda = \frac{h}{p} = \frac{hc}{\sqrt{E^2 - m_0^2c^4}} = \frac{hc}{\sqrt{(m_0c^2 + E_{kin})^2 - m_0^2c^4}}$$

$$\lambda = \frac{hc}{\sqrt{2m_0c^2E_{kin} + E_{kin}^2}}$$

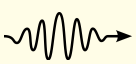
If $E_{kin} << m_0c^2$:

$$\lambda \approx \frac{h}{\sqrt{2m_0E_{kin}}}$$

If $E_{kin} >> m_0c^2$:

$$\lambda \approx \frac{h}{E_{kin}}$$

In QED, as in other quantum field theories, we can use the little pictures invented by my colleague Richard Feynman, which are supposed to give the illusion of understanding what is going on in quantum field theory.



**– Murray Gell-Mann**

## ✓ Allowed reactions

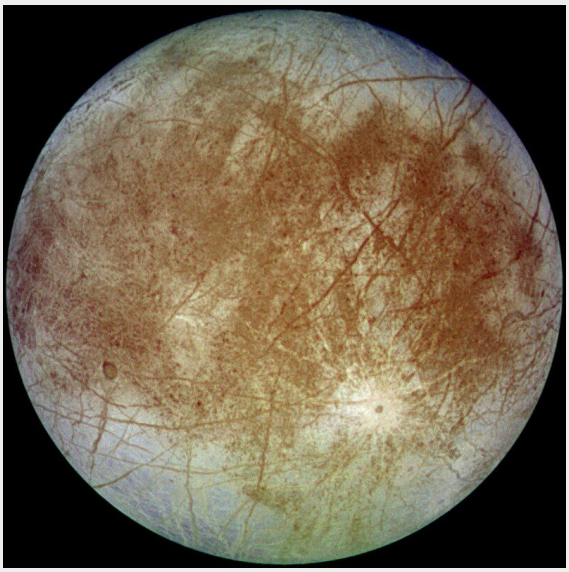
**Reactions that are allowed or permitted by the laws of physics**

(Conserve certain fundamental quantities such as energy, momentum, electric charge, and lepton number)

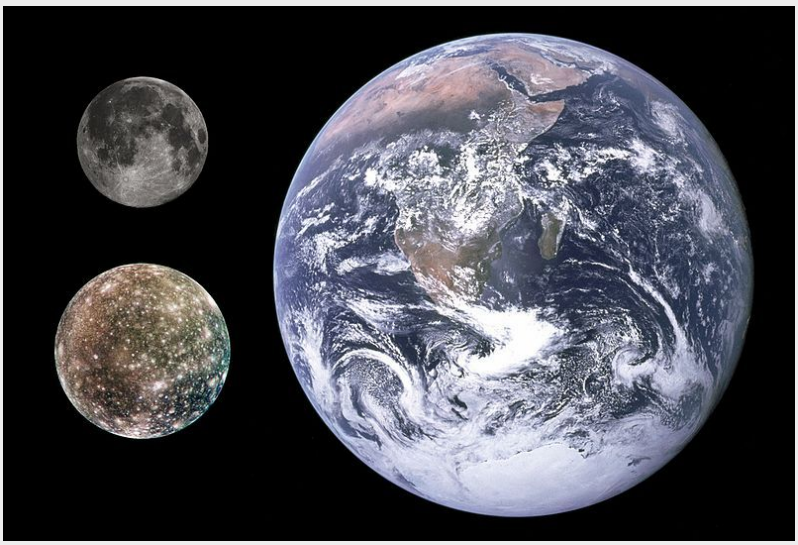
## ✓ Forbidden reactions

**Reactions that are not allowed or permitted by the laws of physics**

(Violate one or more of the conservation laws and are, therefore, highly unlikely to occur)



**Europa**, a moon of **Jupiter**, is a potential habitat for extraterrestrial life due to its subsurface ocean of liquid water. The ocean is thought to be heated by **tidal forces** generated by **Jupiter's immense gravity**, which keeps it in a liquid state. The presence of liquid water and potential sources of energy has led scientists to consider **Europa** as a possible habitat for life. The moon's intriguing characteristics have motivated several space missions aimed at exploring and understanding **Europa** further.



- ✓ Size comparison of Earth, Moon and **Callisto** (or **Jupiter IV**, the second-largest moon of Jupiter)
  - **Earth:** The diameter of Earth is approximately 12,742 kilometers (7,917 miles).
  - **Moon:** The diameter of Earth's moon is approximately 3,474 kilometers (2,159 miles)
  - **Callisto:** The diameter of Jupiter's moon is approximately 4,820 kilometers (2,996 miles)

## Fundamental forces of Nature

- **EM** → Long range ( $\frac{1}{R^2}$ )
- **Weak** → Short range ($10^{-21}$ m)
- **Strong** → Short range (< $10^{-15}$ m)
- **Gravity** → Long range ( $\frac{1}{R^2}$ )

## EM + Weak + Strong + Gravity → make the Sun shine

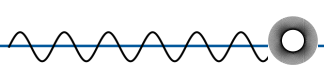


| ✓ **Feynman diagrams** | ✓ **Feynman rules** |
|---|---|
| A pictorial way of representing the interactions of particles in quantum field theory. They are named after **Richard Feynman**, who developed them in the 1940s. | Set of rules to get from a Feynman diagram to the mathematical expression. |





| | **Small** | |
|---|---|---|
| **Fast** | **Classical mechanics** | Quantum mechanics |
| | Relativistic mechanics | **Quantum field theory** |





**Robert Oppenheimer (left) and General Leslie Groves (right) at Ground Zero of the nuclear bomb test site**

## ✓ Five mysteries the Standard Model can't explain

Why do neutrinos have mass?

What is dark matter?

Why is there so much matter in the universe?

Is there a particle associated with the force of gravity?

Why is the expansion of the universe accelerating?

## Virtual black hole

A hypothetical black hole that exists temporarily as a result of a quantum fluctuation of spacetime.

Kinematic description of the Solar System **(Kepler)**

+

Dynamic description of the Solar System **(Newton)**

Development of celestial mechanics

## Planck star

A hypothetical astronomical object that could potentially form when the energy density of a collapsing star reaches the Planck energy density.

1650's to 1700's

↓

Improvements in the telescope

↓

More precise measurements of planet positions

↓

More accurate tests to the theory of gravity

## Electroweak stars

Stars that fall under the hypothesised category of **exotic stars** in which their gravitational collapse is averted due to the presence of **electroweak combustion radiation pressure**. This pressure results from the energy released by electroweak conversion of quarks to leptons. This intriguing process occurs within a core region about the size of an **apple**, housing approximately two times the **mass of Earth** and experiencing extraordinarily **high temperatures** of approximately $10^{15}$ Kelvin.

## Boson star

A theoretical astronomical object, postulated to exist under certain conditions in the realm of astrophysics. Unlike **conventional stars**, which are mainly composed of atoms, **boson stars** are hypothesized to be formed from **bosons** – a type of elementary particle that includes particles like photons, gluons, and W and Z bosons.

## Strange star

A hypothetical type of astronomical object believed to be composed of strange quark matter.

## Preon star

A theoretical type of compact star proposed to be composed of **preons**, which are hypothetical subatomic particles that are considered to be even more fundamental than quarks. These **preons** would be packed at incredibly high densities, surpassing $10^{23}$ kg/m$^3$. **Preon stars** are envisioned to be denser than **quark stars** while being heavier and smaller than **white dwarfs** and **neutron stars**. The idea behind **preon stars** is that under extreme conditions of pressure and density, **preons** may interact to form a new state of matter, creating a unique compact object in the universe. Such **preon stars** could be the result of **supernova explosions** or even trace back to the early moments of the **Big Bang**. Preon stars have been suggested as potential candidates for **dark matter** due to their dense nature and hypothetical properties. However, it is crucial to highlight that **no direct observational evidence** currently supports the existence of **preons** or **preon stars**, making them purely theoretical constructs.

## Quark star

A theoretical type of compact, exotic celestial object that is predicted to be the outcome of the extreme temperature and pressure at its core, causing nuclear particles to come together and create **quark matter**, which is a continuous state of matter composed of free quarks. However, it is important to note that **quark stars** remain theoretical and have not been directly observed or confirmed through empirical evidence. Further investigation and observations are necessary to validate the existence of such exotic objects in the universe.

As the Universe cooled, it went from being radiation dominated (whose energy density was proportional to $\frac{1}{(\text{scale factor of the universe})^4}$) to being matter dominated (whose energy density was proportional to $\frac{1}{(\text{scale factor of the universe})^3}$).

**Dark energy became more important as the Universe expanded.**

✓ Strong + electromagnetic + weak + gravity → **quantum gravity** ($10^{32}$ K)

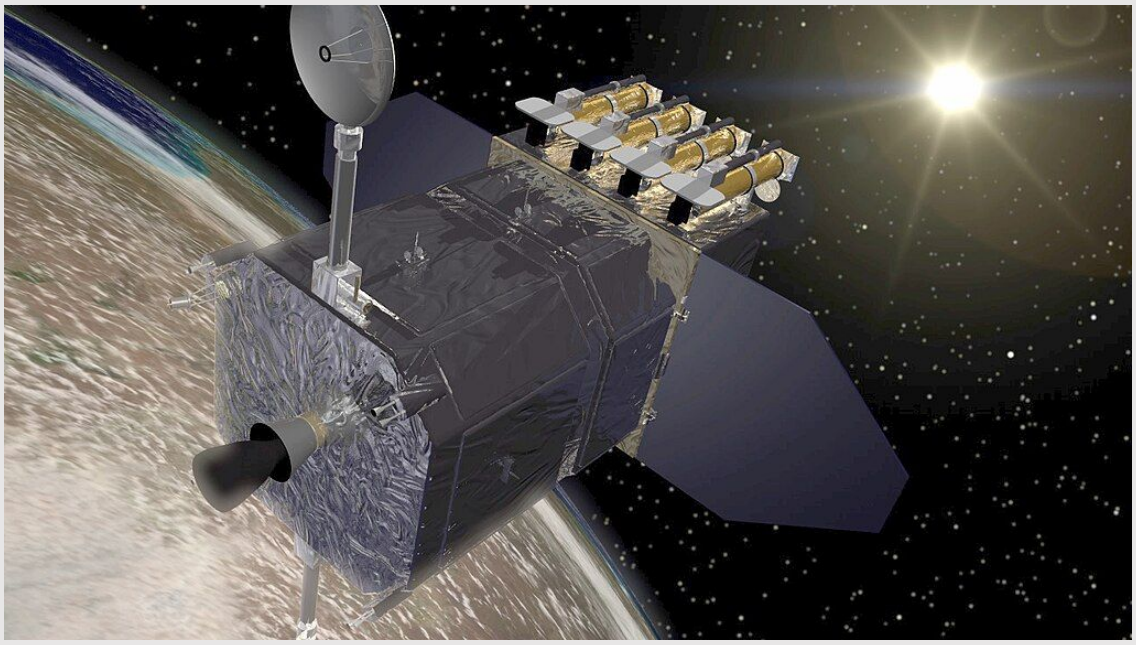
The temperature at which the four fundamental forces of nature (the strong force, electromagnetism, the weak force, and gravity) may be unified into a single force called **quantum gravity**

✓ Strong + electromagnetic + weak → **superforce** ($10^{28}$ K)

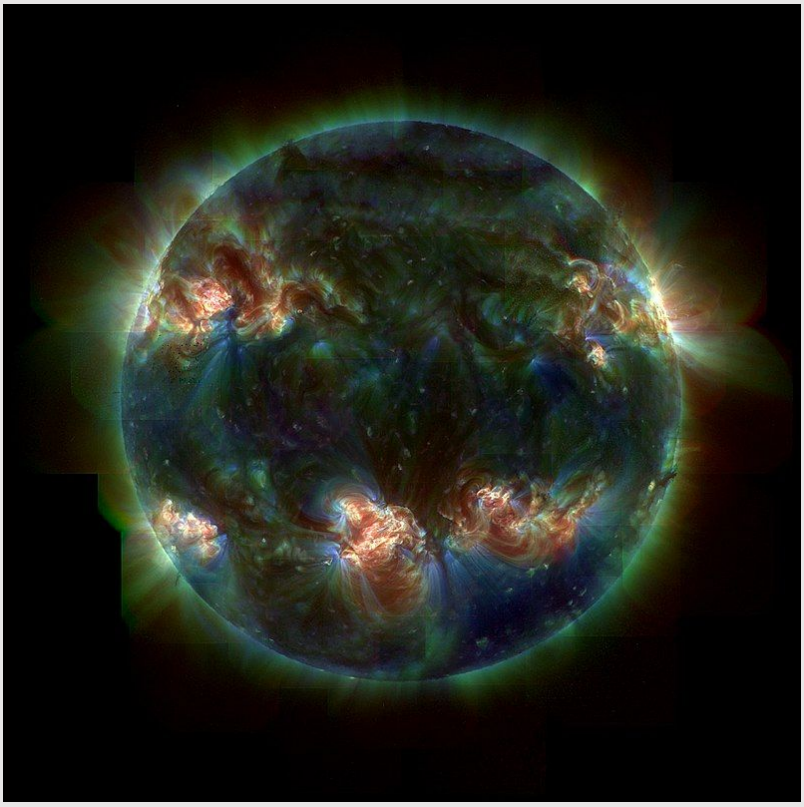
The temperature at which the three fundamental forces of nature (the strong force, electromagnetism, and the weak force) may be unified into a single force called a **superforce**

✓ Electromagnetic + weak → **electroweak** ($10^{15}$ K)

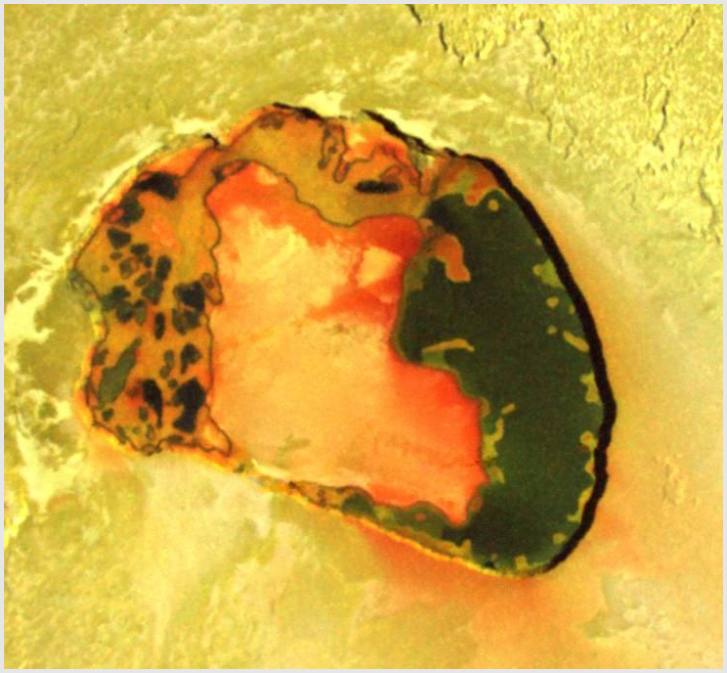
The temperature at which the electromagnetic force and the weak force may be unified into a single force called the **electroweak force**



**The Solar Dynamics Observatory (SDO)**, a satellite launched by NASA on February 11, 2010. Its primary mission is to study the Sun and its dynamic behaviour in order to better understand its impact on space weather and Earth's environment.



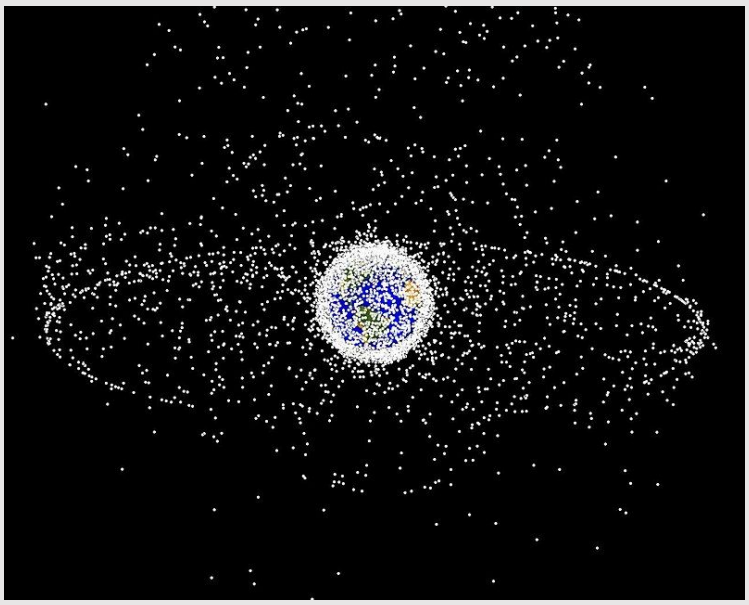
An ultraviolet image of the Sun's active photosphere as viewed by the **TRACE** space telescope



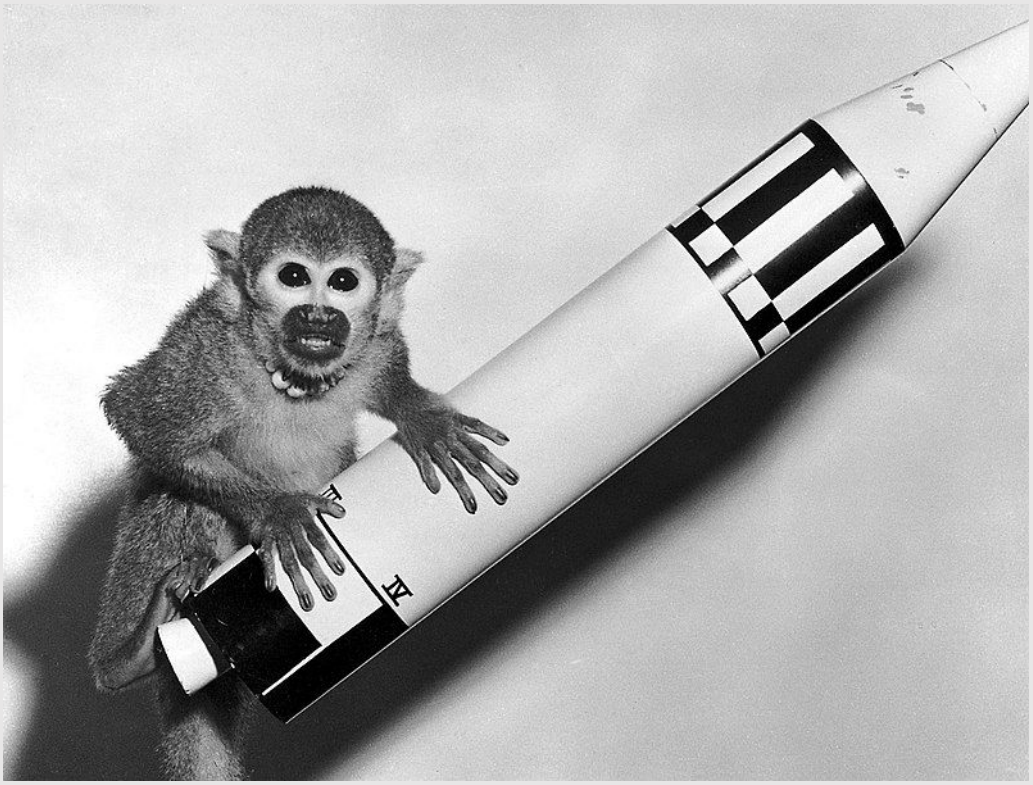
A captured view from NASA's Galileo spacecraft shows the **volcanic crater** named **Tupan Patera** on Jupiter's moon **Io**.

## ✓ Cosmochemistry

The scientific discipline that focuses on the study of the chemical composition of celestial bodies, such as planets, moons, asteroids, comets, meteorites, and stars, in our solar system and beyond. It involves analyzing and understanding the distribution of elements and isotopes in these objects to gain insights into their formation, evolution, and the processes that have shaped them over time.



A computer-generated representation of Space Debris orbiting Earth in 1980, produced by **NASA**.



**Miss Baker** was indeed a space pioneer and a squirrel monkey who made a significant contribution to early space exploration. On May 28, 1959, she became one of the first animals to travel into space and safely return. Miss Baker's historic flight was part of the U.S. space program's efforts to understand the effects of space travel on living organisms.

## ✓ Space neuroscience

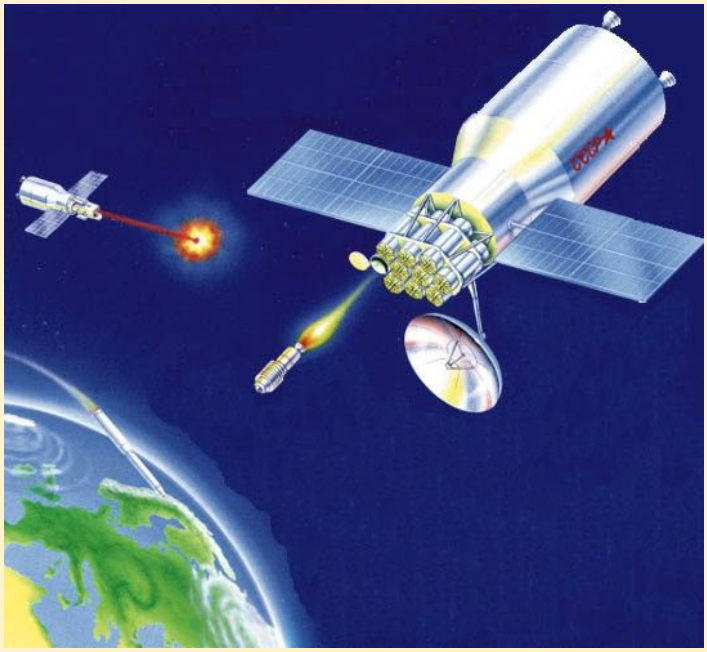
A specialized field of study that focuses on understanding how the space environment affects the nervous system and brain function of astronauts. It also emphasises the scientific investigation of how the human central nervous system functions specifically during and after human spaceflight.



An astronaut on board the **International Space Station** is using head-mounted display to conduct space neuroscience experiment. This experiment is designed to assess how the perception of depth and distance changes in the microgravity environment of space.

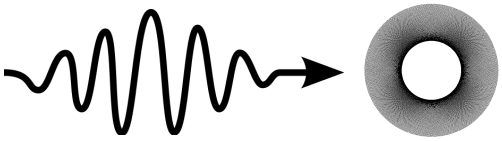
## Space warfare

A theoretical military engagement taking place beyond Earth's atmosphere, specifically in outer space. This involves spacecraft, satellites, and other space-based platforms carrying out military actions and operations.



A depiction created by the United States Air Force showcasing an imaginary space weapon that could belong to the Soviet Armed Forces.

The **inflationary Big Bang** is a scientific theory that explains the rapid expansion of the universe in the fraction of a second following the **Big Bang**. According to the theory, the universe underwent a phase of **exponential expansion**, causing it to increase in size by a factor of at least $10^{26}$. This rapid expansion smoothed out matter and energy, leading to the **homogeneous universe** we observe today. The theory was proposed to solve several problems in cosmology, such as the **horizon problem** and the **flatness problem**, and has been supported by numerous observational and experimental evidence.







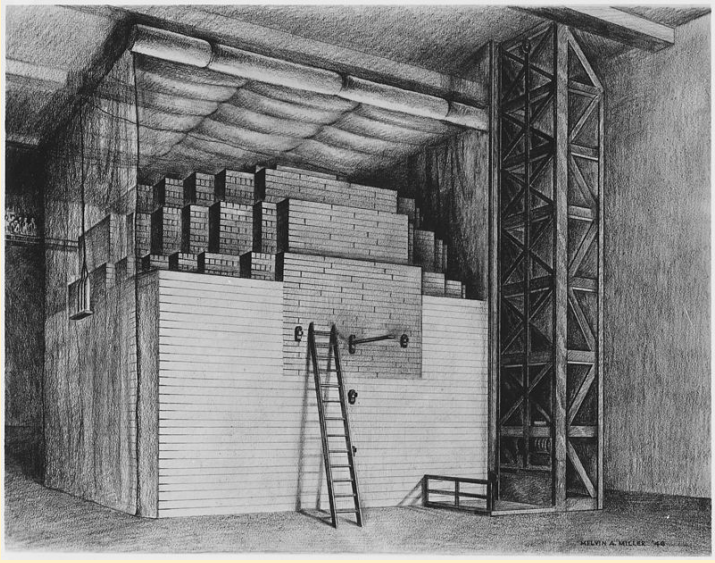
**Robert A. Millikan (1923)**

**Millikan's original oil-drop apparatus**, which was used around 1909 –1910, played a crucial role in his famous oil-drop experiment. This experiment allowed him to accurately measure the charge of an electron, providing essential evidence for the existence of discrete electric charges and contributing significantly to the understanding of atomic and subatomic particles.

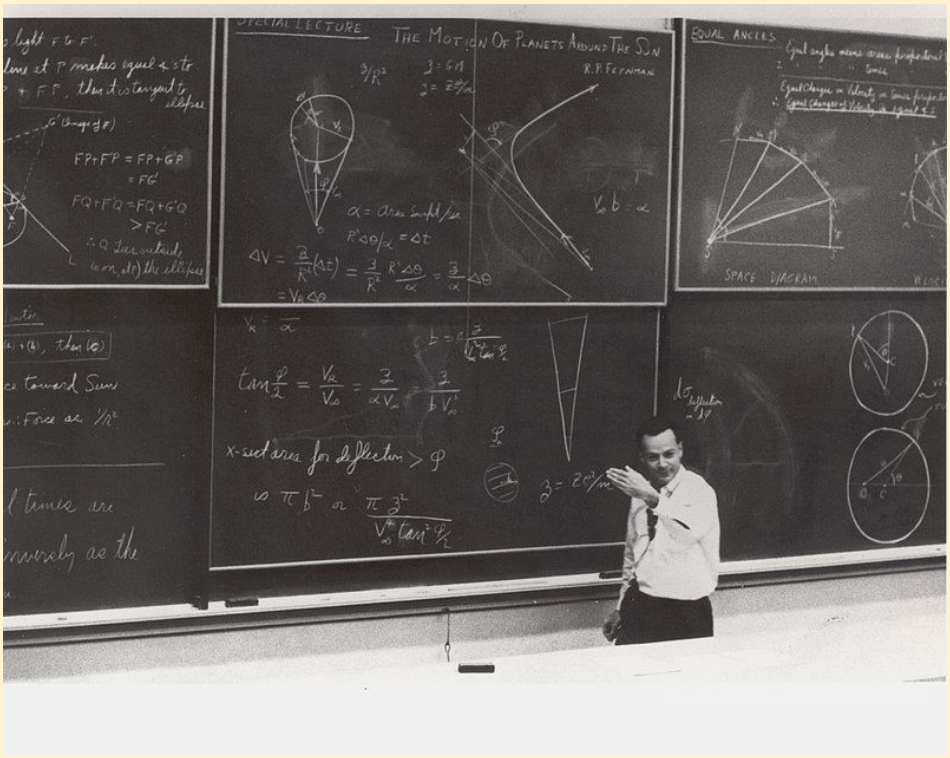


The **Compton Gamma Ray Observatory**, launched into Earth's orbit in 1991, was a significant space observatory designed to study gamma rays, the most energetic form of electromagnetic radiation. This space-based telescope was named in honour of **Arthur Holly Compton**, a Nobel laureate in physics who made pioneering contributions to the understanding of X-ray and gamma-ray phenomena.





**Chicago Pile-1**, the world's first nuclear reactor to achieve a self-sustaining chain reaction, was designed by Fermi. It featured a cubic lattice structure embedded in graphite, containing uranium and uranium oxide.




The renowned physicist **Dr. Richard Feynman** is captured during his Special Lecture on "the Motion of Planets Around the Sun."

## Missing energy

The energy that remains undetected by a particle detector. However, its presence is inferred based on the fundamental principles of energy conservation and momentum conservation.

## Muon capture

The process of capturing a **negative muon** by a **proton** typically leads to the creation of a **neutron** and a **neutrino**. Occasionally, this capture event can also produce a **gamma photon**. This phenomenon is an essential area of study in particle physics, shedding light on the intricate interactions between subatomic particles.

✓ **Ordinary muon capture (OMC):**

negative muon + proton → neutron + neutrino

✓ **Radiative muon capture (RMC):**

negative muon + proton → neutron + neutrino + gamma photon

## Schwinger effect

A static electric field of strength **E** in empty space can create virtual electron-positron ($e^+$ $e^-$) pairs. If the virtual electron-positron ($e^+$ $e^-$) pairs move apart from each other by a distance *l*, they will receive the energy *l*eE from the electric field. If this energy $\geq 2m_ec^2$, the pair will become real and the particles will continue to move apart − thereby causing the decay of the electric field.

✓ **Probability of creating an $e^+$ $e^-$ pair** $\propto \exp\left(-\frac{m_e^2}{eE}\right)$

where e and $m_e$ denote the charge and mass of electron.

## ✔ Third law of Black hole Thermodynamics:



It is impossible to reduce the surface gravity of a black hole to zero by any physical process in a finite number of steps.

The equation of state parameter

$$w = \frac{\text{pressure}}{\text{energy density}}$$

$$\rho \propto a^{-3(w+1)}$$

- $\rho \rightarrow$ density
- $a \rightarrow$ scale factor of the universe

| | |
|---|---|
| **Ordinary baryonic matter** $\rho \propto a^{-3}$ | $w = 0$ (The pressure is negligible compared to the energy density) |
| **Cold dark matter** $\rho \propto a^{-3}$ | $w = 0$ (The pressure is negligible compared to the energy density) |
| **Radiation** $\rho \propto a^{-4}$ | $w = \frac{1}{3}$ (The pressure is equal to the one-third of the energy density) |
| **Dark energy** $\rho \rightarrow$ constant | $w = -1$ (The pressure is equal to the negative of the energy density) |

✓ When considering the total pressure of the universe, one needs to take into account the positive pressure contribution from radiation and the negative pressure contribution from dark energy.

$$\textbf{Total pressure} = P_R + P_\Lambda = \frac{4\sigma T^4}{3c} - \rho_\Lambda c^2$$

The energy of an oscillation of length *l* is given by:

$$E = \frac{\hbar c}{l}$$

This means that the energy of an oscillation increases as the length *l* decreases. The gravitational potential created by the mass **m**, at this length is given by:

$$\varphi = \frac{Gm}{l}$$

This means that the greater the mass, the greater the gravitational potential. The smaller the length *l*, the greater the gravitational potential. Due to the equivalence of mass and energy, as described by **Einstein's formula**:

$$m = \frac{E}{c^2} = \frac{\hbar}{lc}$$

$$\varphi = \frac{G\hbar}{l^2 c}$$

The **Planck length** is the scale at which the laws of quantum mechanics become important in the fabric of spacetime. It is a very small unit of length, approximately $1.616 \times 10^{-35}$ meters. At this scale, the effects of gravity and quantum mechanics become so strong that they cannot be ignored and the spacetime is expected to be so quantum that the laws of classical geometry **(Euclidean geometry)** may not apply. The notion of smooth, continuous **spacetime** breaks down at such tiny scales, and one would need a theory of quantum gravity to describe the geometry accurately. It is true that as we approach the **Planck Length**, the geometry associated with the gravitational field will deviate more and more from **Euclidean Geometry**.

The **degree of deviation** $\zeta$ of geometry from **Euclidean geometry** in the gravitational field is determined by the ratio of the gravitational potential $\varphi$ and the square of the speed of light c:

$$\zeta = \frac{\varphi}{c^2} = \frac{(\text{Planck length})^2}{l^2}$$

When $\zeta << 1$, the geometry is close to Euclidean geometry. However, as $\zeta$ approaches 1, the geometry deviates more and more from Euclidean geometry. For $\zeta = 1$, the Euclidean geometry is completely distorted.

$\sqrt{\frac{G\hbar}{c^3}}$ → The length at which the Euclidean geometry is completely distorted.





- The kinetic energy (KE) of an object in motion is given by the formula: $KE = \frac{mv^2}{2}$
- The potential energy (PE) of an object in a gravitational field is given by: $PE = -\frac{GMm}{R}$
- The total energy (E) of the object is the sum of its kinetic energy and potential energy:

$$E = KE + PE = \frac{mv^2}{2} - \frac{GMm}{R} = \frac{m}{2}(v^2 - v_{escape}^2)$$

- If $v > v_{escape}$: E is positive
- If $v = v_{escape}$: E is 0
- If $v < v_{escape}$: E is negative

**Pair production process:**

photon + nucleus → nucleus + electron + positron

In this process, a photon with an energy of 1.022 MeV interacts with the electric field of a nucleus, and due to the conservation of energy and momentum, the photon's energy is converted into the mass energy of the electron and positron pair.

## Gell-Mann – Nishijima formula:

A formula that relates the **electric charge** "**Q**" of a particle to its **isospin** "**$I_3$**" and **hypercharge** "**Y**". It is named after **Kazuhiko Nishijima** and **Murray Gell-Mann**, who independently proposed the formula in 1953 and 1956, respectively.

$$\frac{Q}{e} = I_3 + \frac{1}{2} Y$$

A proton has an isospin of $I_3 = +\frac{1}{2}$ and a hypercharge of Y = 1. So, we can calculate the electric charge of a proton as follows:

$$\frac{Q}{e} = +\frac{1}{2} + \frac{1}{2} \quad (1)$$

$$\frac{Q}{e} = +\frac{1}{2} + \frac{1}{2}$$

Q = +1e

The electric charge (Q) of a proton is +1e. This means that a proton has one unit of positive electrical charge.

A neutron has an isospin of $I_3 = -\frac{1}{2}$ and a hypercharge of Y = 1. So, we can calculate the electric charge of a neutron as follows:

$$\frac{Q}{e} = -\frac{1}{2} + \frac{1}{2} \quad (1)$$

$$\frac{Q}{e} = -\frac{1}{2} + \frac{1}{2}$$

Q = 0

The electric charge (Q) of a neutron is 0, meaning it has no net electric charge. Neutrons are electrically neutral particles.

✔ Supersymmetry + gravity → **SUPERGRAVITY**

A symmetry that relates particles with integral spin **(bosons)** to particles with half-integral spin **(fermions)** and vice versa.

## Matter - Antimatter Asymmetry

| Matter Particles | Antimatter Particles |
| --- | --- |
| 10,000,000,001 | 10,000,000,000 |

Also known as the **baryon asymmetry of the universe**, refers to the fact that there is an apparent imbalance between matter and antimatter in the observable universe. It is one of the most important unanswered questions in particle and cosmological physics. According to the **Big Bang theory**, the universe began with equal amounts of matter and antimatter. When matter and antimatter particles come into contact, they annihilate each other, converting their mass into energy. If this were the case, all matter and antimatter would have annihilated, leaving behind only radiation. However, our universe is dominated by matter, and very little antimatter is observed. This is evident from the fact that stars, planets, and galaxies are all made of matter, and we do not observe significant regions of antimatter in the cosmos. In physics, the cause of this **matter-antimatter asymmetry** is yet unknown. The term **"baryogenesis"** refers to a process that is generally acknowledged as the cause of this imbalance. **Baryogenesis** suggests that in the early universe, there were processes that violated certain symmetries and conservation laws, leading to a slight excess of matter over antimatter.

"The views of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. Henceforth, space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality."



**– Hermann Minkowski**



Minkowski in 1883, at the time of being awarded the Mathematics Prize of the French Academy of Sciences.

The formula for calculating the **baryon number** "B" of a particle is quite simple:

$$B = \frac{1}{3}\left(n_q - n_{\bar{q}}\right)$$

where $n_q$ is the number of quarks, and $n_{\bar{q}}$ is the number of antiquarks. It's important to note that the baryon number only applies to baryons (such as protons and neutrons) and not to other types of particles like mesons, leptons, or gauge bosons. Let's use this formula to calculate the baryon number of a specific particle:

**Example:** Λ (Lambda) Particle

The **Λ (Lambda)** particle is a type of **baryon** composed of three quarks: up, down, and strange quarks. Its quark composition is (u, d, s).

- ✓ Number of quarks = 3 (u, d, s)
- ✓ Number of antiquarks = 0 (since there are no antiquarks in a **Λ particle**)

$$B = \frac{1}{3}(3 - 0) = 1$$

So, the baryon number of the Λ (Lambda) particle is +1.




**Quark structure of the lambda baryon**

## Ammonia planet

A theoretical type of planet with a high ammonia content. May have ammonia lakes or oceans.

## Blanet

A hypothetical category of **exoplanets** that directly orbits black holes. They are thought to be possible in the accretion disks of **supermassive black holes**. The accretion disk is a region of gas and dust that is spiraling into the black hole. The high temperatures and pressures in the accretion disk could allow planets to form.

## Eyeball planet

A tidally locked planet where uneven heating of the surface induces spatial features resembling a human eye

## Vitriolic planet



A hypothetical type of exoplanet with oceans of liquid sulphuric acid on its surface. The surface of a **vitriolic planet** would be very hot and acidic, and it would be impossible for life as we know it to exist there. However, the acidic oceans could potentially harbour a unique form of life that is adapted to the harsh conditions. **Vitriolic planets** are a very hypothetical type of exoplanet, and there is no direct evidence that they exist. However, they are a fascinating possibility, and they could potentially teach us a lot about the diversity of life in the universe.

## Tidally detached exomoon

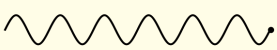


A planet that was originally a moon but has become gravitationally detached.

## Toroidal planet

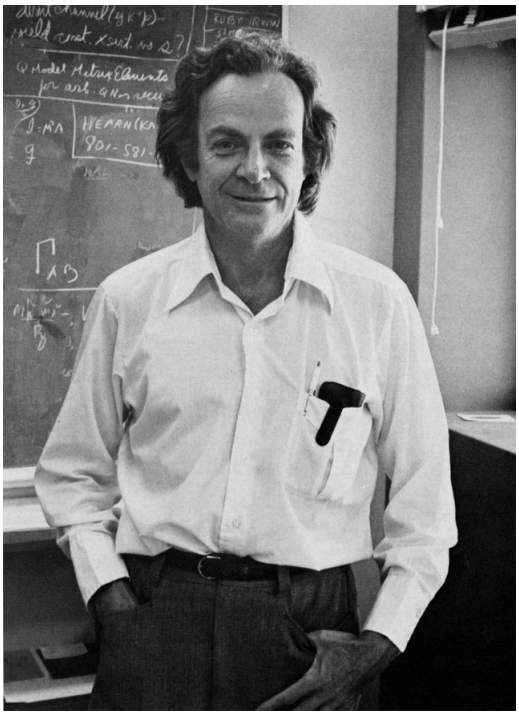
A planet whose shape resembles a torus or doughnut.

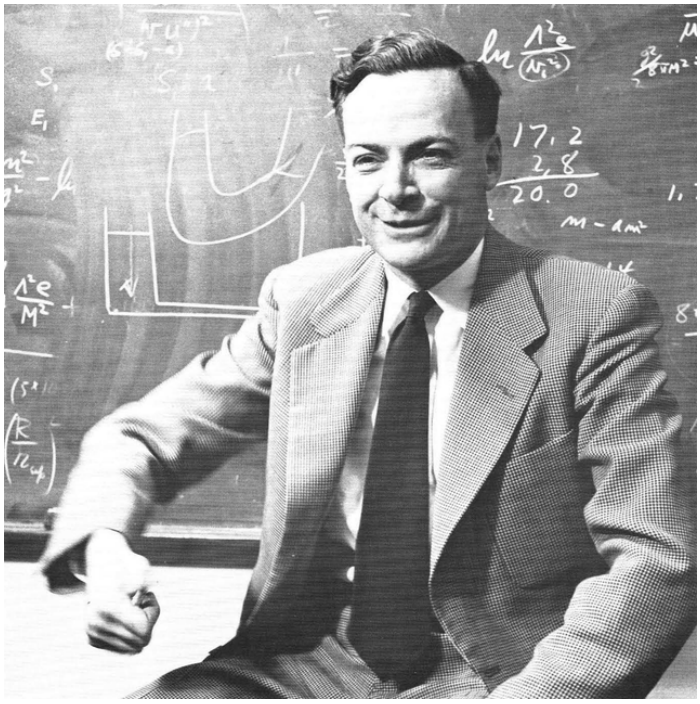
## Chlorine planet



A hypothetical type of exoplanet that contains significant amounts of free chlorine or hydrochloric acid.

**The physicist, mathematician, and futurist, Freeman Dyson wrote in a letter to his parents this beautiful description of the complex personality of Richard Feynman:**





"Feynman is the young American professor, half genius and half buffoon, who keeps all physicists and their children amused with his effervescent vitality. He has, however, as I have recently learned, a great deal more to him than that, and you may be interested in his story. The part of it with which I am concerned began when he arrived at Los Alamos; there he found and fell in love with a brilliant and beautiful girl, who was tubercular and had been exiled to New Mexico in the hope of stopping the disease. When Feynman arrived, things had got so bad that the doctors gave her only a year to live, but he determined to marry her and marry her he did; and for a year and a half, while working at full pressure on the Project, he nursed her and made her days cheerful. She died just before the end of the war.

I was wrong when I wrote that Feynman found his wife Arlene in New Mexico. He married her first in a city hall on Staten Island and then took her with him to New Mexico. The story is movingly told by Feynman in the book What Do You Care What Other People Think? (1988), the title being a quote from Arlene.

As Feynman says, anyone who has been happily married once cannot long remain single, and so yesterday we were discussing his new problem, this time again a girl in New Mexico with whom he is desperately in love. This time the problem is not tuberculosis,but the girl is a Catholic. You can imagine all the troubles this raises, and if thereis one thing Feynman could not do to save his soul, it is to become a Catholic himself. So we talked and talked and sent the sun down the sky and went on talking in the darkness. At the end of it, Feynman was no nearer to the solution of his problems,but it must have done him good to get them off his chest. I think that he will marry the girl and that it will be a success, but far be it from me to give advice toanybody on such a subject."

**(March 8, 1948)**

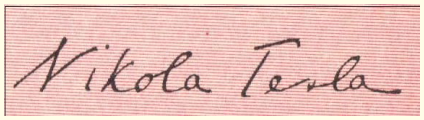
- Special relativity + Quantum mechanics → **Relativistic electrodynamics** (very precise and highsuccessful)
- Quantum mechanics + gravity → **Theories of quantum gravity** (many theories, but no data to test them)
- Electromagnetism + Quantum mechanics + gravity → Planck scale of mass, length and time (no data)

**Stellification**

A theoretical process that involves transforming a brown dwarf star or a Jovian-class planet (a gas giant like Jupiter) into a star, or significantly increasing the luminosity of dim stars.








✓ **Heike Kamerlingh Onnes' Laboratory in Leiden, Netherlands, 1926. Oppenheimer is in the middle row, second from the left.**

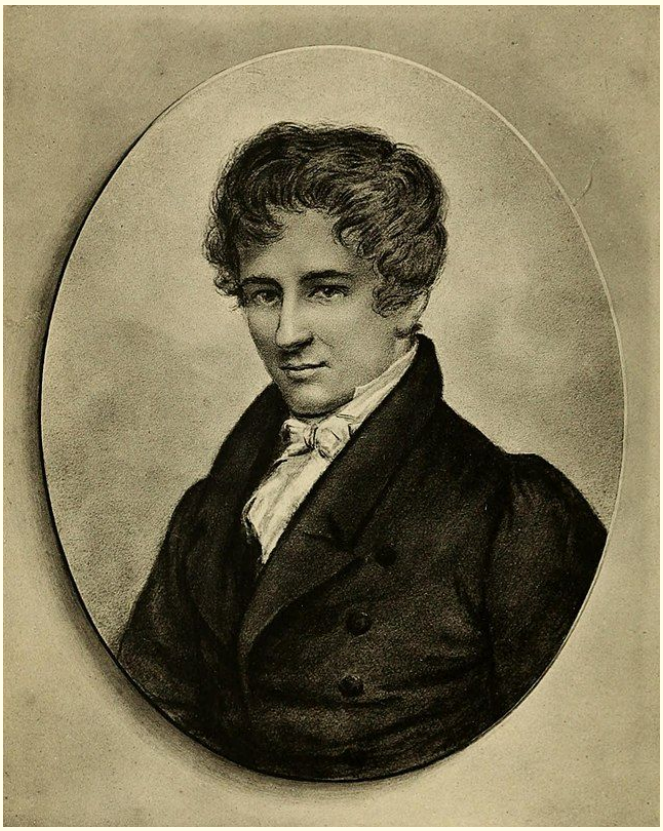
"[The function] resembles the outer edge of the finest of needles, pointing vertically upwards from its base. Away from that base, [its] numerical value is zero, but its height is such that the area enclosed between the perimeter and the base is one unit."

Tough Dirac acknowledged that the function was unrigorous, he noted it could be used 'as though it were a proper function for practically all purposes in quantum mechanics.'

Later, he remarked that his study of engineering led him to it:

"I think it was that sort of training that gave me the idea of the delta function because when you think of load in engineering structures, sometimes you have a distributed load, and sometimes you have a concentrated load at the point. It is [...] the same whether you have a concentrated load or a distributed one, but you use somewhat different equations in the two cases. [I]t's only to unify these two things which sort of led to the delta function."

⭐ – **Graham Farmelo**



N. H. Abel

The Norwegian mathematician **Niels Henrik Abel** died at the tragically young age of 26 years old of tuberculosis.

During his short life, he suffered from poverty, starvation, and painful frustration while trying hopelessly to find a university teaching position.

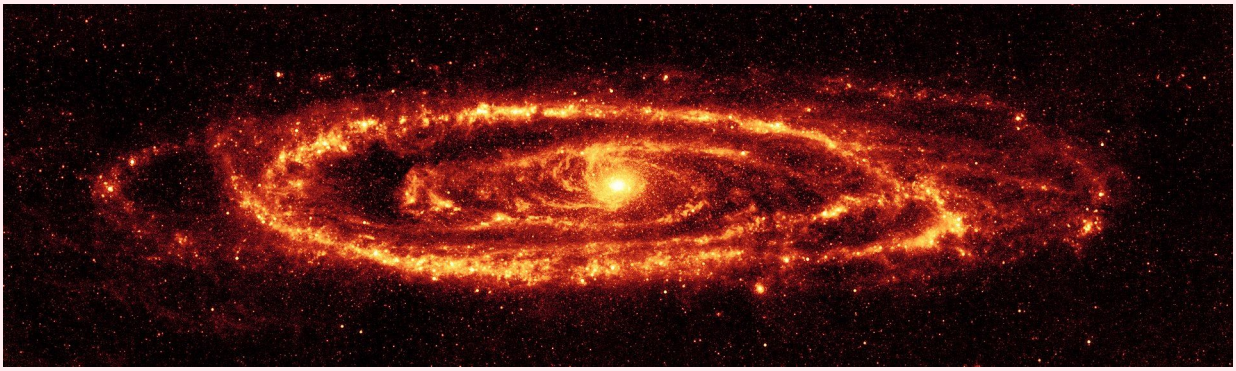
Abel made a multitude of fundamental contributions to various fields of mathematics, the most famous one probably being the proof of the impossibility of solving quintic equations in terms of radicals (independently of the work of the French mathematician Évariste Galois). Today, anyone who reads books on advanced mathematics will find his name in several theorems and theories.

✓ **The great French mathematician Charles Hermite said about Abel:**

**"He has left mathematicians something to keep them busy for five hundred years."**

**In a famous letter to Winteler the great scientist Albert Einstein wrote:**

"Unthinking respect for authority is the greatest enemy of truth."



**Cosmic dust of the Andromeda Galaxy as revealed in infrared light by the Spitzer Space Telescope.**

**Wien's displacement law:**

$$\lambda_{peak} T = \frac{hc}{4.9651 k_B}$$

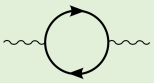
If $\lambda_{peak}$ = Planck length:

$$T = \frac{2\pi}{4.9651} \times \text{Planck temperature}$$

✓ $T = 1.264 \times$ Planck temperature

If the peak wavelength is equal to the Planck length, the corresponding temperature would be extremely high, on the order of Planck temperature. This is much higher than any temperature that has ever been observed or measured in the universe.

**Super-Earth** – Planet with a mass between Earth and Uranus



## Collapsar

A star which has undergone gravitational collapse.

When a star exhausts its fuel for fusion reactions, its fate depends on its mass. If the star's mass is less than the **Chandrasekhar limit** (1.4 solar masses), it will stabilize and contract, transforming into a white dwarf. If its mass lies between the **Chandrasekhar limit** and the **Tolman–Oppenheimer–Volkoff limit** (around 3 solar masses), it will evolve into a neutron star. However, if its mass exceeds the **Tolman–Oppenheimer–Volkoff limit**, the star will undergo gravitational collapse and turn into a black hole.



## Quark-nova

The hypothetical violent explosion resulting from the conversion of a neutron star to a quark star



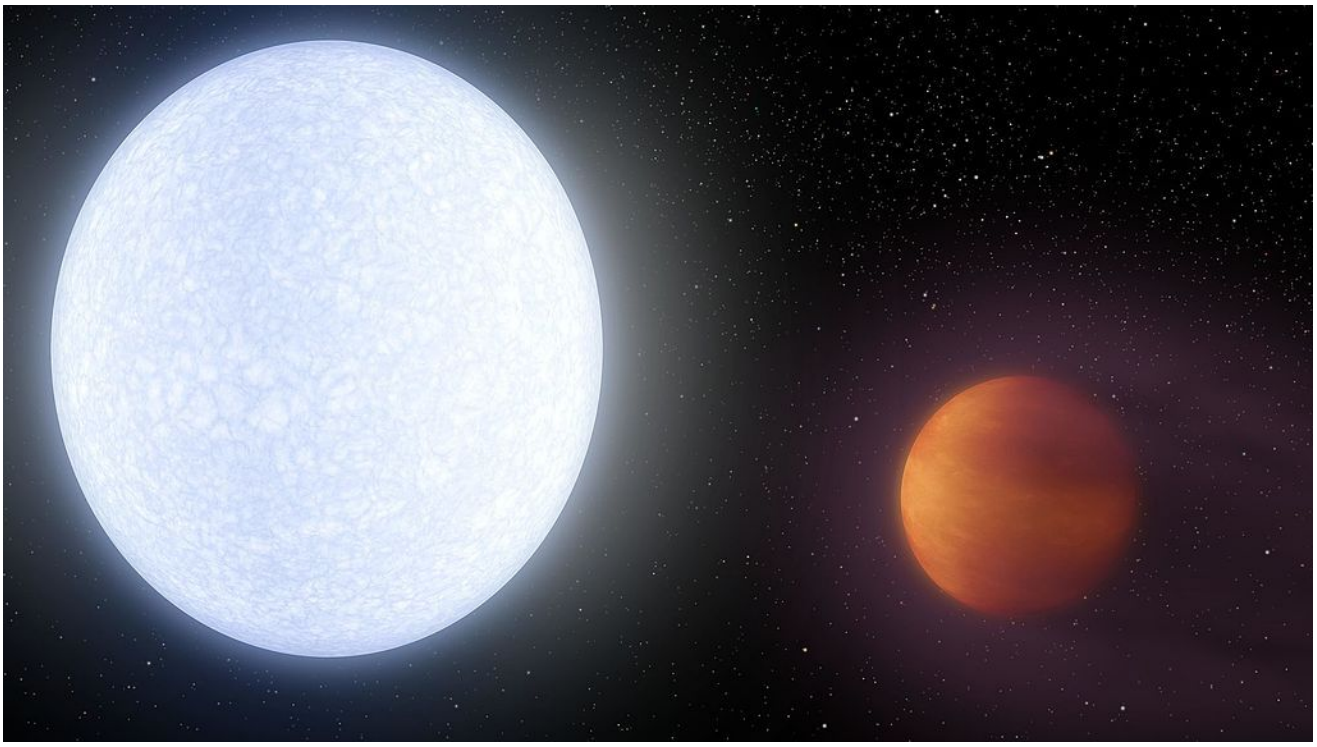
Artistic illustration of **79 Ceti b**, the first exoplanet discovered outside our solar system with a minimum mass smaller than that of Saturn.

### Chthonian planet

A hypothetical type of planet that are formed when the atmosphere of a gas giant is stripped away by the intense radiation of its star. This process, called **hydrodynamic escape**, leaves behind a rocky or metallic core that resembles a terrestrial planet in many respects. They are named after the **Greek god of the underworld**, **Chthon**. They are also sometimes called **"naked cores"** or **"stripped down planets."**

### If Newton's Gravity isn't true, why do we still use it?

- It's a good approximation for most engineering applications.



Artistic depiction of exoplanet **KELT-9b** orbiting its host star, **KELT-9**

**12 free nucleons** → **$^{12}$C nucleus**

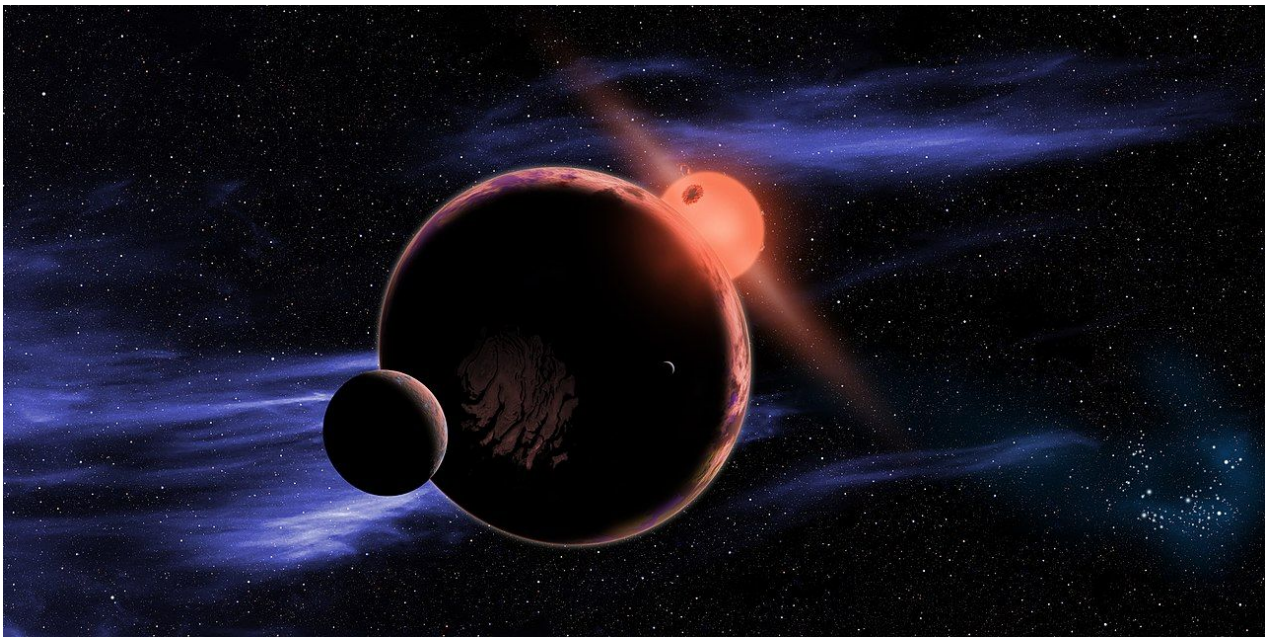
(High entropy) (Low entropy)

**Neptunian Desert**

Stellar region without planets equivalent to or above Neptune

## Mega-Earth

A massive terrestrial exoplanet that is at least ten times the mass of Earth



An artistic depiction of a planet with two **exomoons** orbiting in the habitable zone of a **red dwarf**.



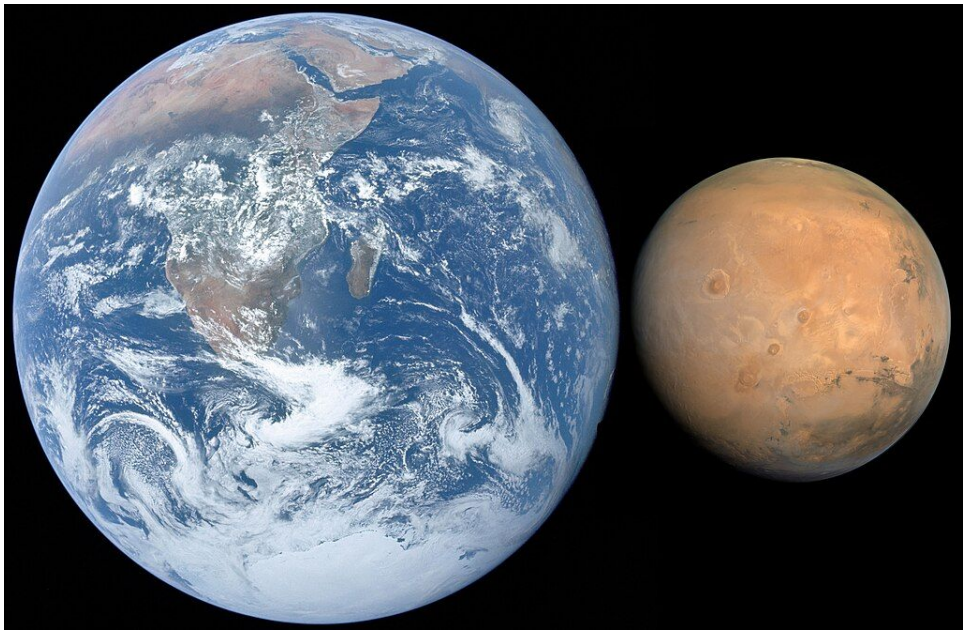
Hubble Space Telescope image of the **nebula M1-67** and the **Wolf–Rayet star** WR 124 in the center

## Coreless planet

A planet that has no metallic core. Instead, it is made up of a thick layer of rock and minerals. Coreless planets can form in cooler regions of space, far from the star they orbit.

## Desert planet

A planet that is dry and has a surface similar to Earth's hot deserts. **Mars** is the only present example of a desert planet in our solar system. It has a very thin atmosphere and receives very little sunlight, which makes it a very cold and dry planet. The surface of Mars is covered in red dust and has many volcanoes and canyons.

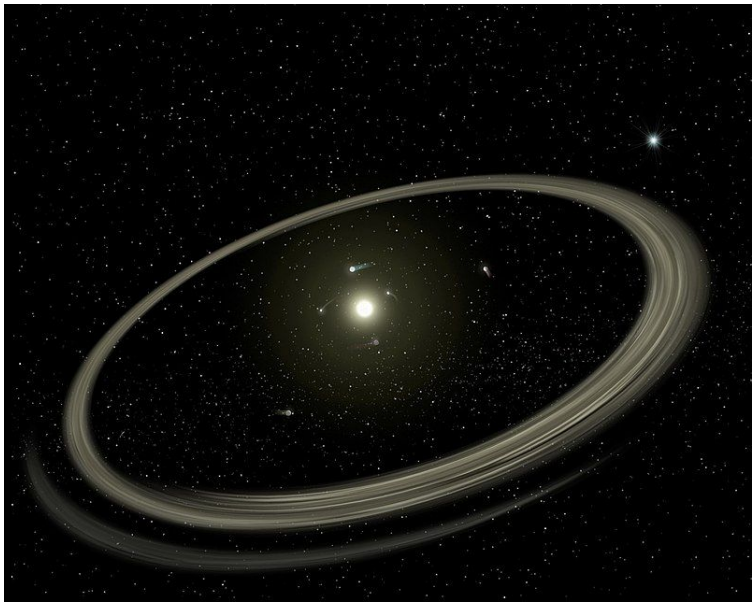


**Size comparison of Earth and Mars.**

- **Earth:** The diameter of Earth is approximately 12,742 kilometers (7,917 miles).
- **Mars:** The diameter of Mars is about 6,779 kilometers (4,212 miles).

## Hycean planet

A hypothetical type of planet that is covered in liquid water and has a hydrogen atmosphere. The presence of liquid water makes **hycean planets** promising candidates for supporting life. More research is needed to learn more about these planets and their potential for habitability.



**An artistic conception of a planetary system**

## Lava planet

A type of terrestrial planet that has a surface that is mostly or entirely covered by molten lava. The surface is constantly molten, and the atmosphere is full of poisonous gases. It is unlikely that life could exist on a lava planet.

## Earth analog

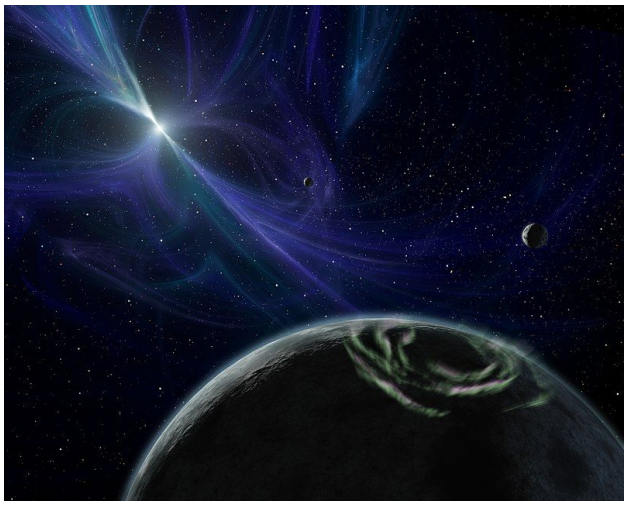
A planet, and even potentially a superhabitable one, could possess conditions that are comparable to those found on Earth.

## Substellar object

Commonly referred to as a **substar**, is indeed an astronomical object with a mass that is smaller than the minimum mass required to sustain stable hydrogen fusion in its core. This minimum mass is known as the **hydrogen-burning limit** or the **deuterium-burning limit** and is approximately 0.08 solar masses, which is equivalent to about 80 times the mass of Jupiter.

## Eccentric Jupiter

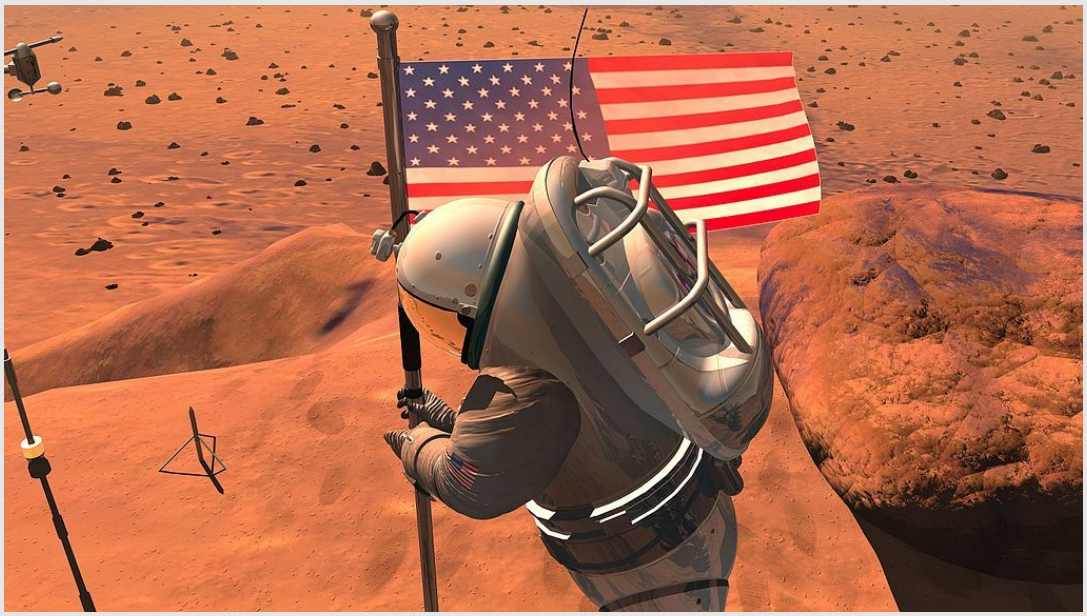
A gas giant that orbits its star in an eccentric orbit.



A depiction created by an artist showcasing the planets orbiting the **neutron star** Lich.

## In situ resource utilization

The concept of utilizing resources available at a specific location or environment rather than relying solely on importing resources from elsewhere. In space exploration, **in situ resource utilization** (ISRU) involves utilizing the resources present on celestial objects, such as the Moon, Mars, asteroids, and other planets, rather than relying solely on Earth-based supplies.



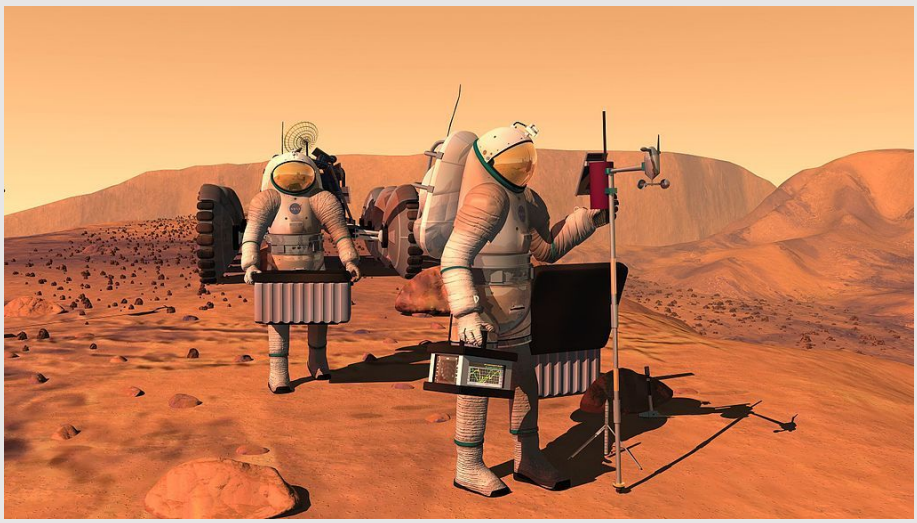
An artist's rendition, created by **NASA**, portrays an astronaut on Mars, in the act of planting a United States flag on the Martian surface.

## Back contamination

The potential contamination of Earth's environment by biological or chemical substances brought back from other celestial bodies, such as planets, moons, asteroids, or comets.

## Forward contamination

The potential transfer of biological material, such as microorganisms or organic compounds, from Earth to other celestial bodies, particularly during space exploration missions.



An artistic conception by **NASA** showcases two individuals wearing spacesuits on the **Martian surface**, engaged in the task of setting up weather equipment.



**NASA** lab photograph of **Lunar Sample 61016**, famously known as **Big Muley**, which is the largest rock brought back from the Moon during the Apollo program. This rock, a breccia, was discovered and collected by the astronauts of the Apollo 16 mission.

## ✓ Space debris

Also known as **space junk**, refers to defunct human-made objects in Earth's orbit that no longer serve any useful purpose. These objects can be remnants of past space missions, defunct satellites, spent rocket stages, or fragments resulting from collisions and explosions. Space debris poses significant risks to both operational spacecraft and crewed missions, as well as to the long-term sustainability of space activities.

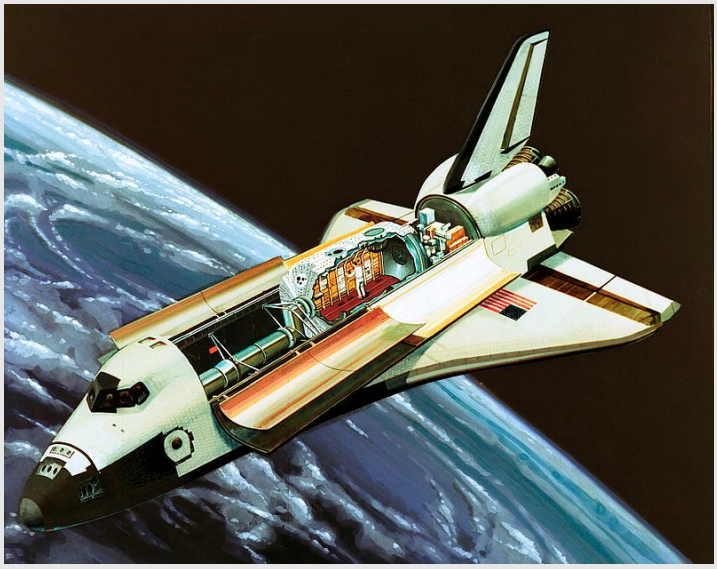
## Space sustainability

The responsible and long-term use of outer space to ensure that current and future generations can continue to benefit from and explore the space environment without causing significant harm or jeopardizing the ability to use space for peaceful purposes. It involves the management and preservation of the space environment, including Earth's orbit and celestial bodies, to prevent the accumulation of space debris, minimize space traffic congestion, and promote the ethical and sustainable utilization of space resources.



A **satellite collision** occurs when two space objects, such as satellites, spacecraft, or space debris, collide with each other in Earth's orbit or in outer space. These collisions can have serious consequences, leading to potential damage or destruction of the satellites involved and the generation of additional space debris.

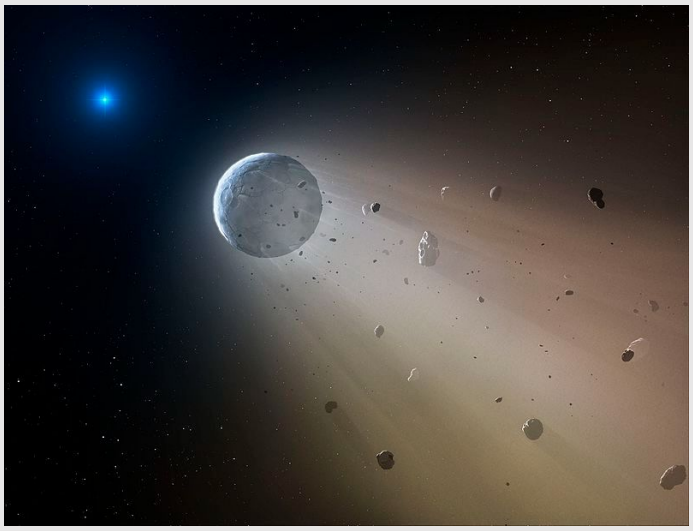




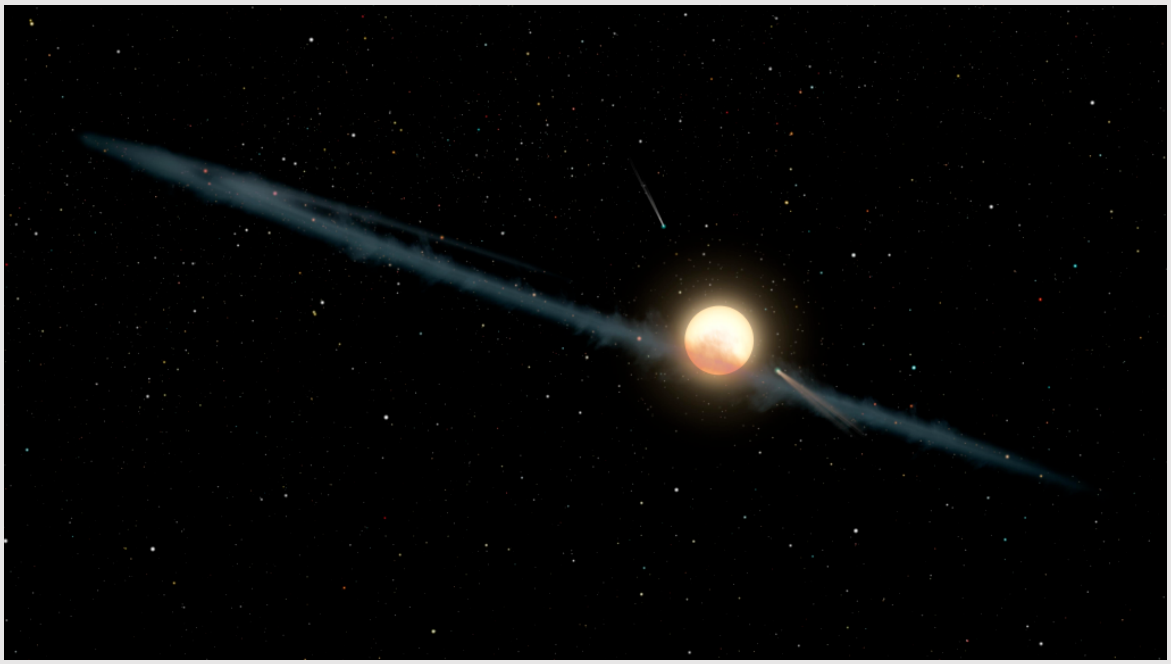
Artistic conception of **Spacelab,** a modular laboratory concept used by NASA and other space agencies to conduct scientific research in space.

## Disrupted planet

A celestial body, such as a planet, exoplanet, moon, planetesimal, exomoon, or asteroid, that has been broken apart, disrupted, or destroyed due to the gravitational forces exerted by a nearby or passing astronomical object, such as a star or another massive celestial body.



Artistic depiction of a white dwarf devouring a minor planet.



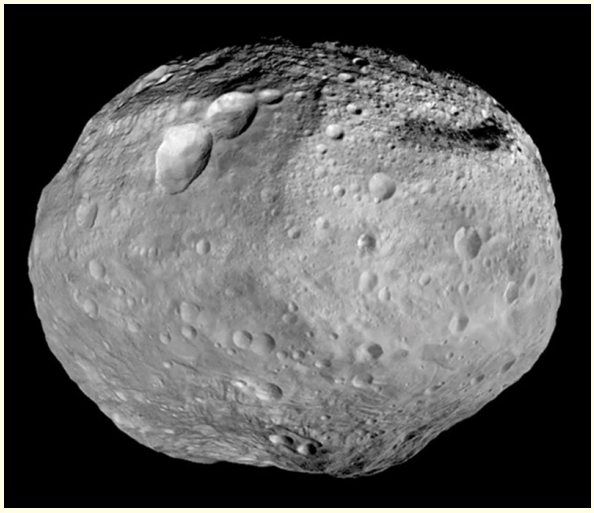
Artistic depiction of an "uneven ring of dust" surrounding Tabby's Star.

## Mesoplanets

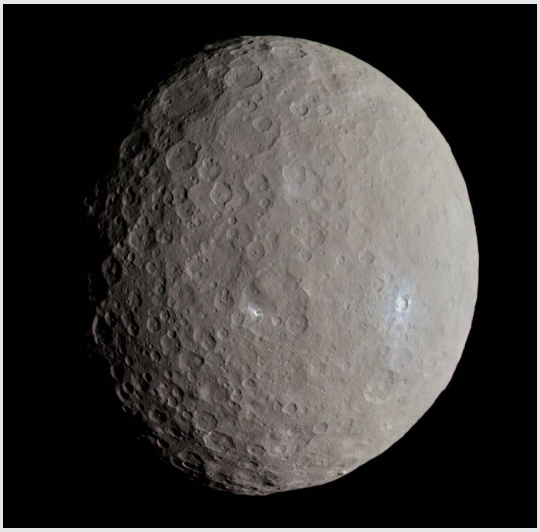
As coined by Isaac Asimov, **mesoplanets** are planetary-mass objects that have sizes smaller than Mercury but larger than Ceres, the largest object in the asteroid belt. These objects fall in the intermediate size range between typical planets and smaller celestial bodies like asteroids and dwarf planets.

## Protoplanet

An astronomical entity, roughly comparable in size to the Moon, emerges through the mutual gravitational pull of **planetesimals** (objects formed from dust, rock, and other materials).These objects are believed to collide and gradually coalesce, leading to the formation of planets.



Vesta



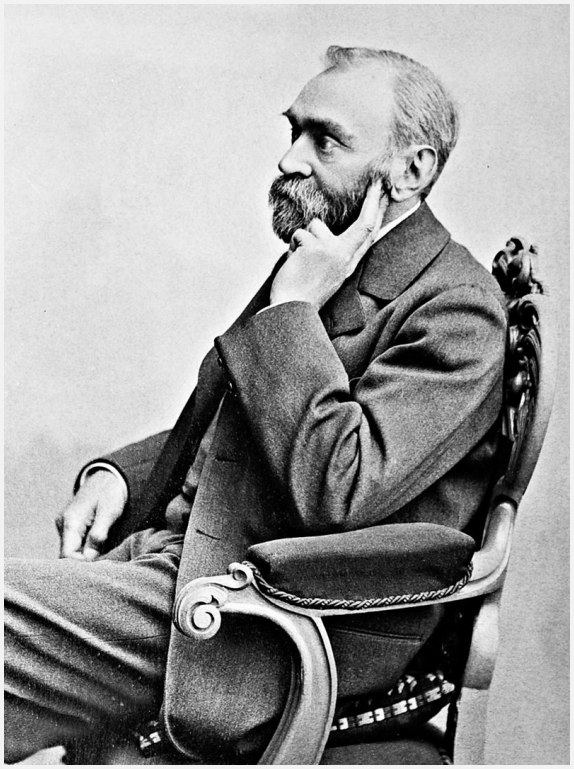
Ceres

**Vesta** and **Ceres** are indeed considered two of the largest surviving **protoplanets** in our solar system. Both **Vesta** and **Ceres** are located in the **asteroid belt**, which is a region between Mars and Jupiter, containing numerous small celestial bodies. These two objects are much larger and more massive than typical asteroids, making them notable representatives of the **protoplanet** category.




✓ **Ceres and Vesta, Moon size comparison**

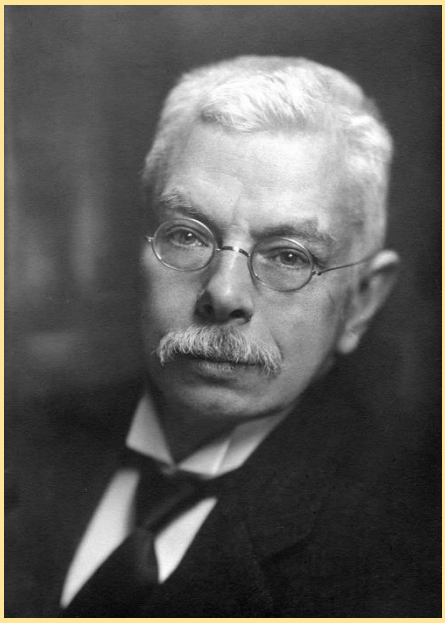
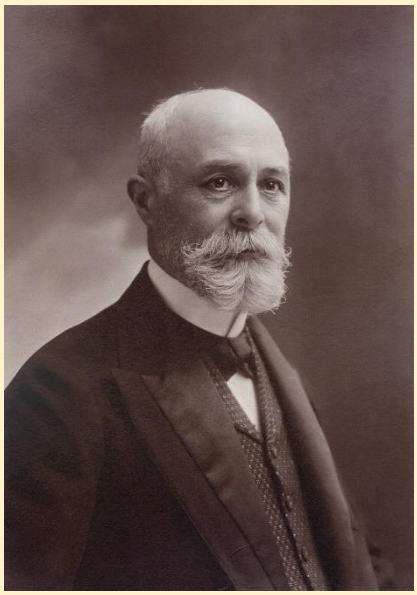


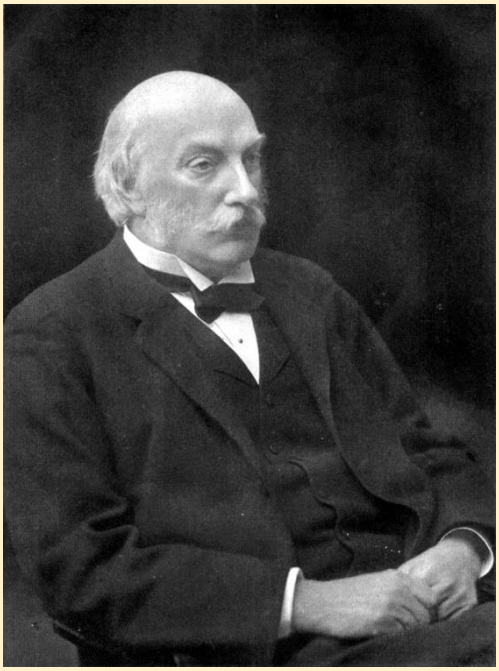


**Alfred Nobel** (1833−1896) was a Swedish chemist, engineer, and inventor who is best known for inventing dynamite. He was born in Stockholm, Sweden, and came from a family of inventors and engineers. After studying chemistry and engineering in various European cities, **Nobel** began to experiment with different explosives, ultimately inventing **dynamite i**n 1867. Despite the success of his invention, **Nobel** was deeply troubled by its destructive power and its use in warfare. In 1888, his brother Ludvig died, and a French newspaper mistakenly published an obituary for **Alfred Nobel**, calling him the **"merchant of death"** for his **invention of dynamite**. This event deeply affected Nobel, and he decided to use his vast fortune to leave a more positive legacy. As a result, **Nobel** wrote his will in 1895, in which he left the bulk of his fortune to establish the **Nobel Prizes**. The prizes, which are awarded annually, recognize outstanding achievements in physics, chemistry, medicine, literature, and peace. A prize for economics was added later. Today, the **Nobel Prizes** are among the most prestigious awards in the world, and recipients are recognized for their contributions to the betterment of humanity.

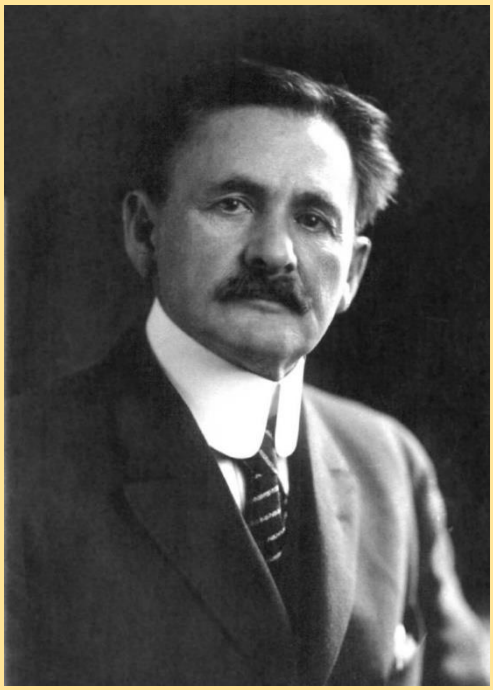
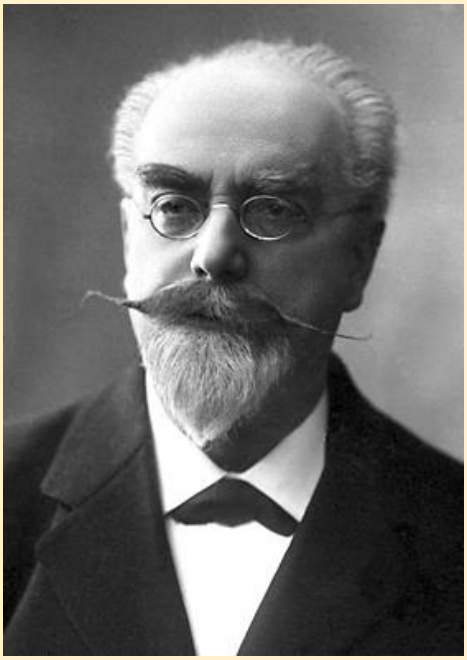
# ✓ Nobel Prizes in physics

| Year | Name | Accomplishment |
|---|---|---|
| **1901** |  **Wilhelm Conrad Röntgen** | Discovery of X-rays |
| **1902** |  **Hendrik Antoon Lorentz** | Investigation of the influence of magnetism on radiation |

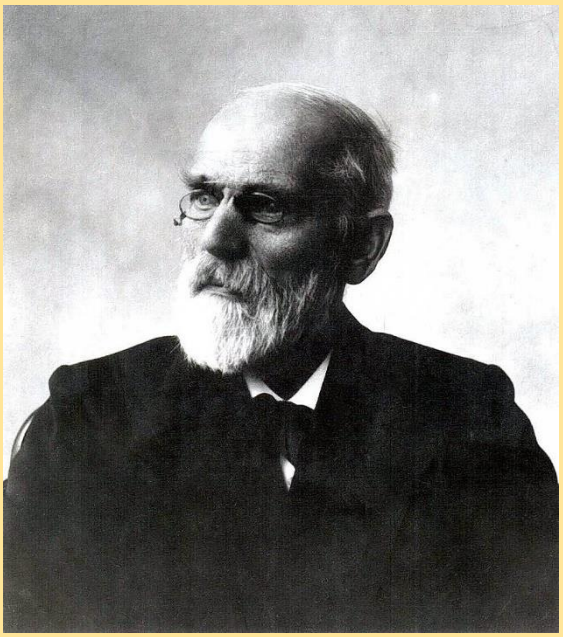
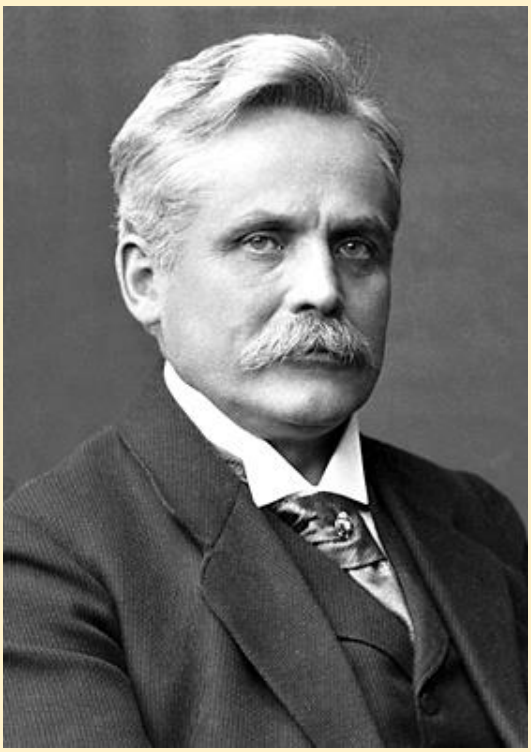
| | | |
|---|---|---|
| |  <br>**Pieter Zeeman** | Investigation of the influence of magnetism on radiation<br>  |
| **1903** |  <br>**Henri Becquerel** | Discovery of spontaneous radioactivity<br>  |

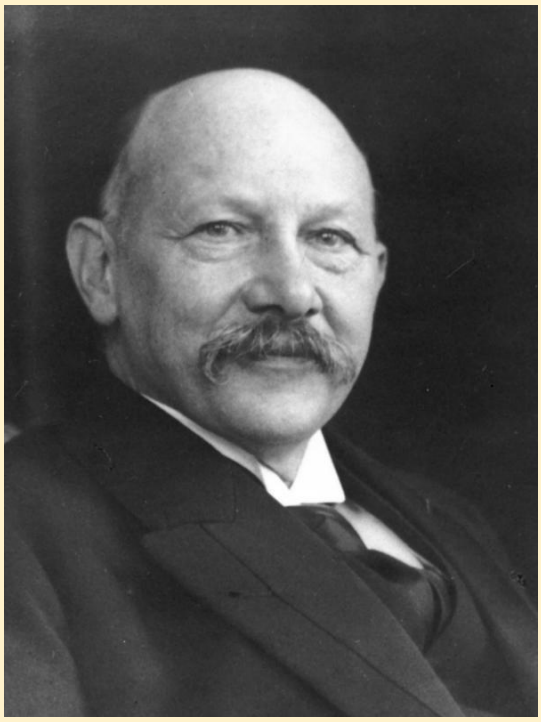
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|---|---|---|
| |  <br>**Pierre Curie and Marie Curie** | Investigations of radiation phenomena discovered by Becquerel |
| **1904** |  <br>**Lord Rayleigh** | Discovery of argon |

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| **1905** |  <br>**Philipp Lenard** | Research on cathode rays |
| **1906** |  <br>**Sir J.J. Thomson** | Research on electrical conductivity of gases |

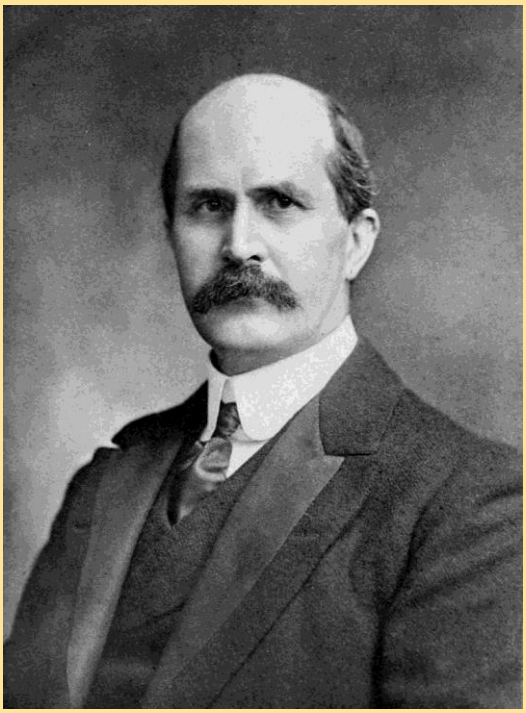
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|---|---|---|
| **1907** |  <br>**A.A. Michelson** | Spectroscopic and metrological investigations<br>  |
| **1908** |  <br>**Gabriel Lippmann** | Photographic reproduction of colours<br>  |

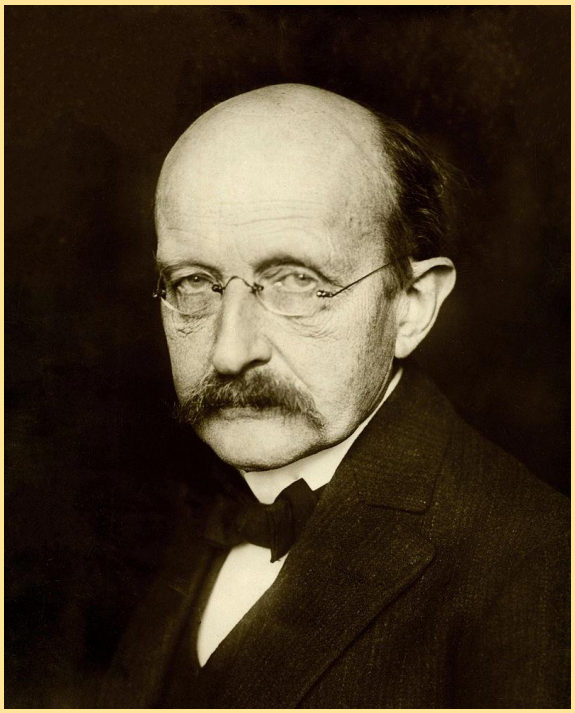
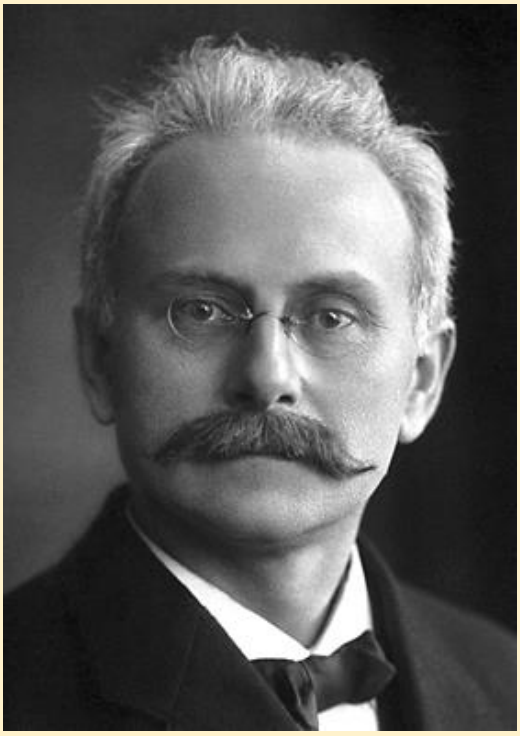
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|---|---|---|
| **1909** |  <br>**Ferdinand Braun** | Development of wireless telegraphy<br>  |
| |  <br>**Guglielmo Marconi** | Development of wireless telegraphy<br>  |

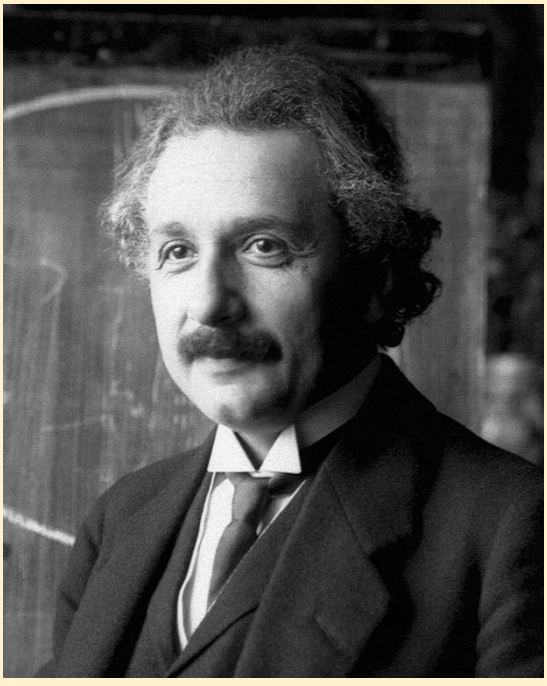
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|---|---|---|
| **1910** |  <br>**Johannes Diederik van der Waals** | Research concerning the equation of state of gases and liquids |
| **1911** |  <br>**Wilhelm Wien** | Discoveries regarding laws governing heat radiation |

| | | |
|---|---|---|
| **1912** |  <br>**Nils Dalén** | Invention of automatic regulators for lighting coastal beacons and light buoys |
| **1913** |  <br>**Heike Kamerlingh Onnes** | Investigation into the properties of matter at low temperatures; production of liquid helium |

| | | |
|---|---|---|
| **1914** |  <br>**Max von Laue** | Discovery of diffraction of X-rays by crystals<br>  |
| **1915** |  <br>**Sir Lawrence Bragg** | Analysis of crystal structure by means of X-rays<br>  |

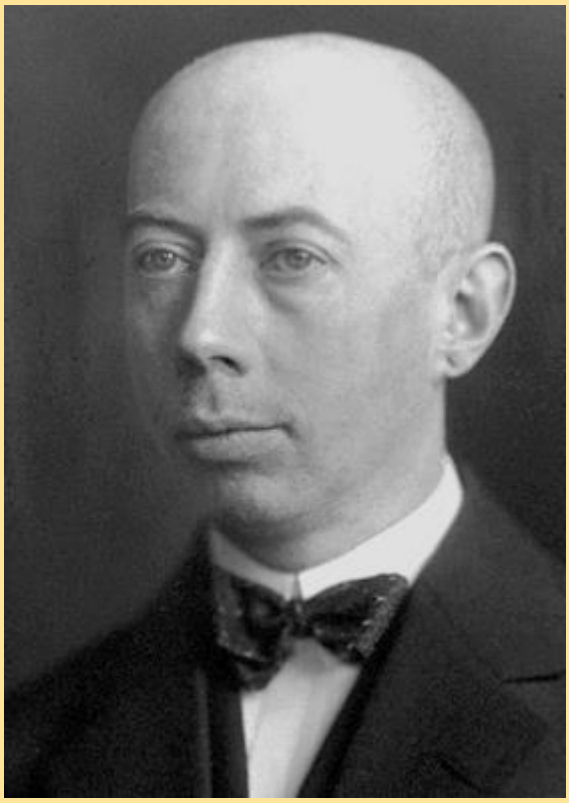
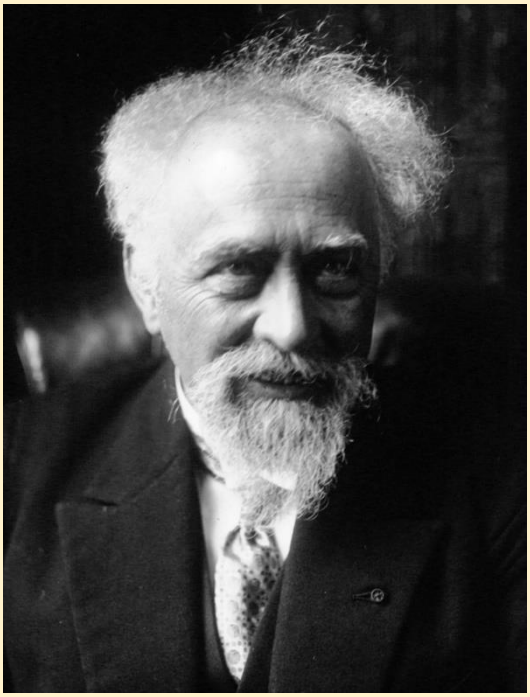
| | | |
|---|---|---|
| |  <br>**Sir William Bragg** | Analysis of crystal structure by means of X-rays<br>  |
| **1917** |  <br>**Charles Glover Barkla** | Discovery of characteristic X-radiation of elements<br>  |

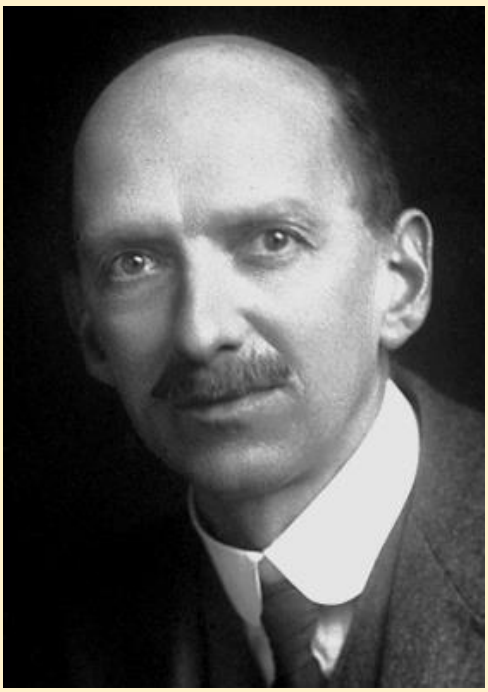
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|---|---|---|
| **1918** |  <br>**Max Planck** | Discovery of the energy quanta<br>  |
| **1919** |  <br>**Johannes Stark** | Discovery of the Doppler effect in positive ion rays and splitting of spectral lines in an electric field<br>  |

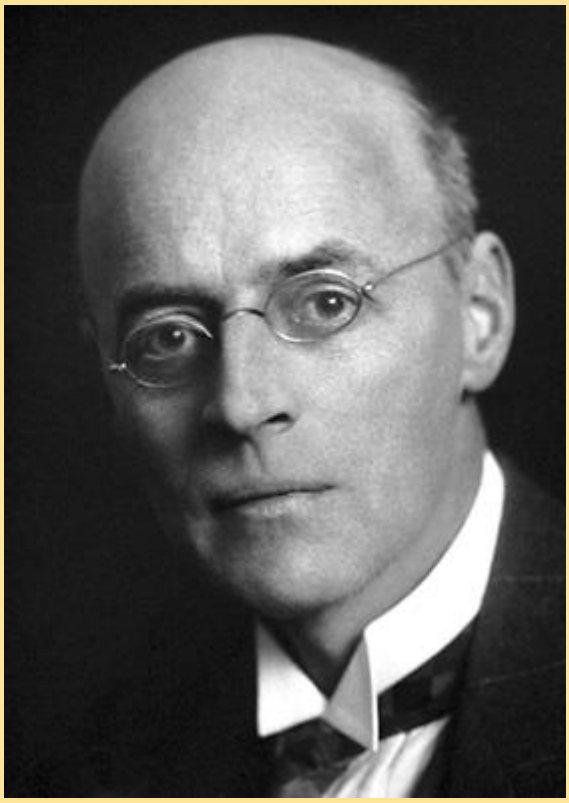
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| **1920** |  <br>**Charles Édouard Guillaume** | Discovery of anomalies in alloys<br>  |
| **1921** |  <br>**Albert Einstein** | Discovery of the law of the photoelectric effect<br>  |

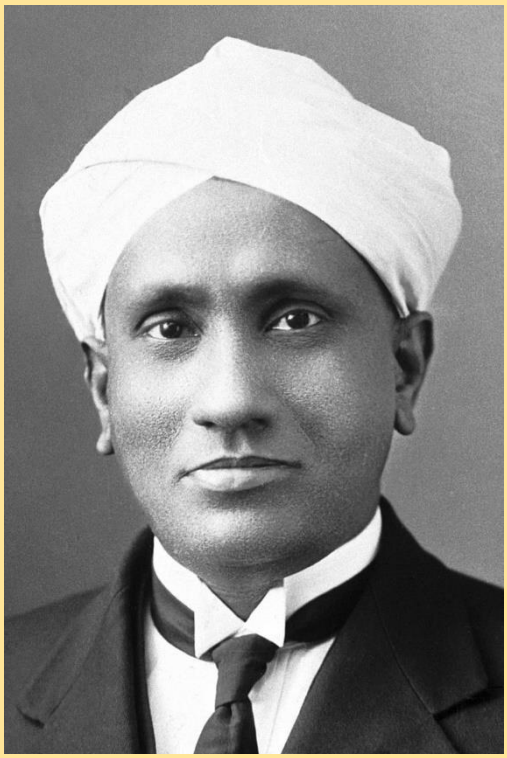
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| **1922** |  <br>**Niels Bohr** | Investigation of atomic structure and radiation<br>  |
| **1923** |  <br>**Robert Andrews Millikan** | Work on elementary electric charge and the photoelectric effect<br>  |

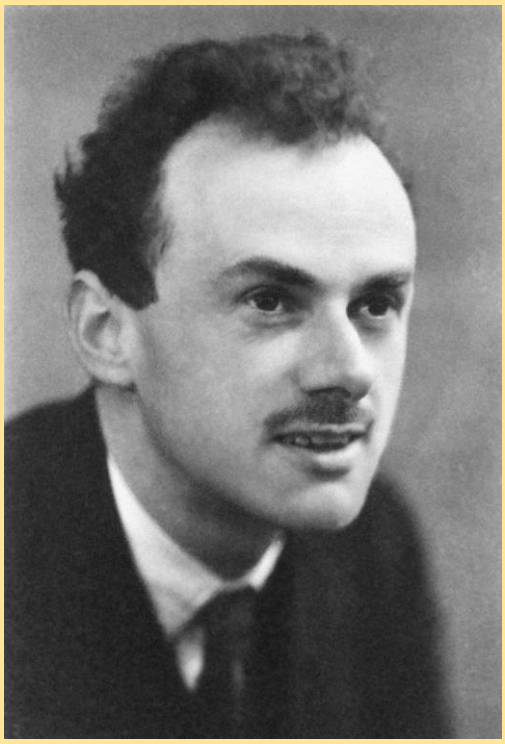
| | | |
|---|---|---|
| **1924** |  <br>**Karl Manne Georg Siegbahn** | Work in X-ray spectroscopy |
| **1925** |  <br>**James Franck** | Discovery of the laws governing the impact of an electron upon an atom |

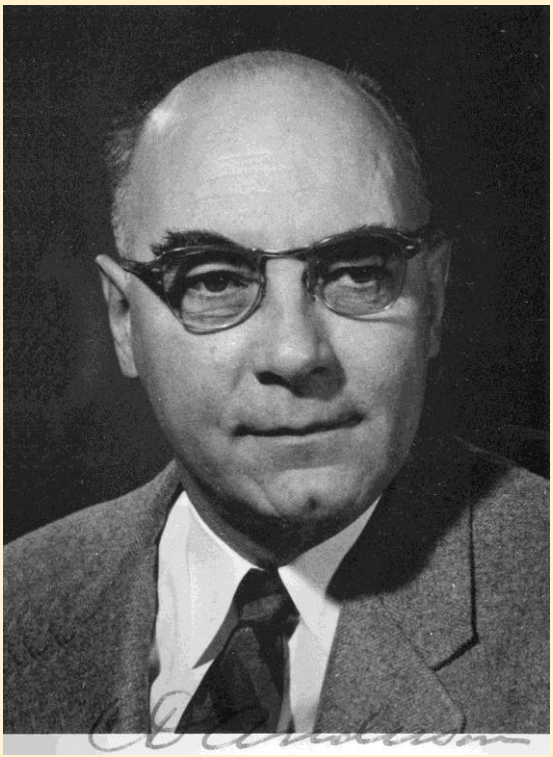
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| |  <br>**Gustav Hertz** | Discovery of the laws governing the impact of an electron upon an atom |
| **1926** |  <br>**Jean Perrin** | Work on the discontinuous structure of matter |

| | | |
|---|---|---|
| **1927** |  <br>**Arthur Holly Compton** | Discovery of the effect named after him<br>  |
| |  <br>**C.T.R. Wilson** | Method of making the paths of electrically charged particles visible by condensation of vapour<br>  |

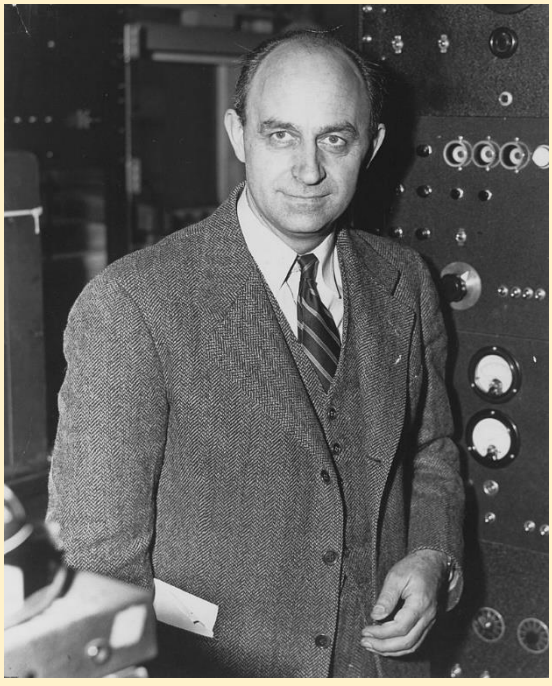
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| **1928** |  <br>**Sir Owen Willans Richardson** | Work on electron emission by hot metals<br>  |
| **1929** |  <br>**Louis de Broglie** | Discovery of the wave nature of electrons<br>  |

| | | |
|---|---|---|
| **1930** |  <br>**Sir Chandrasekhara Venkata Raman** | Work on scattering of light; discovery of the effect named after him |
| **1932** |  <br>**Werner Heisenberg** | Creation of quantum mechanics |

| | | |
|---|---|---|
| **1933** |  <br>**P.A.M. Dirac** | Introduction of wave equations in quantum mechanics<br>  |
| |  <br>**Erwin Schrödinger** | Introduction of wave equations in quantum mechanics<br>  |

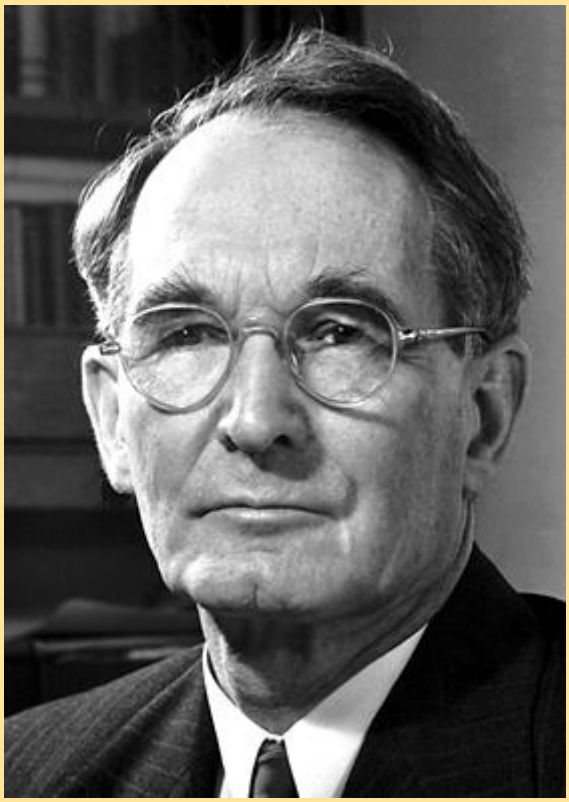
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|---|---|---|
| **1935** |  <br>**Sir James Chadwick** | Discovery of the neutron |
| **1936** |  <br>**Carl David Anderson** | Discovery of the positron |

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|---|---|---|
| |  <br>**Victor Francis Hess** | Discovery of cosmic radiation |
| **1937** |  <br>**Clinton Joseph Davisson** | Experimental demonstration of the interference phenomenon in crystals irradiated by electrons |

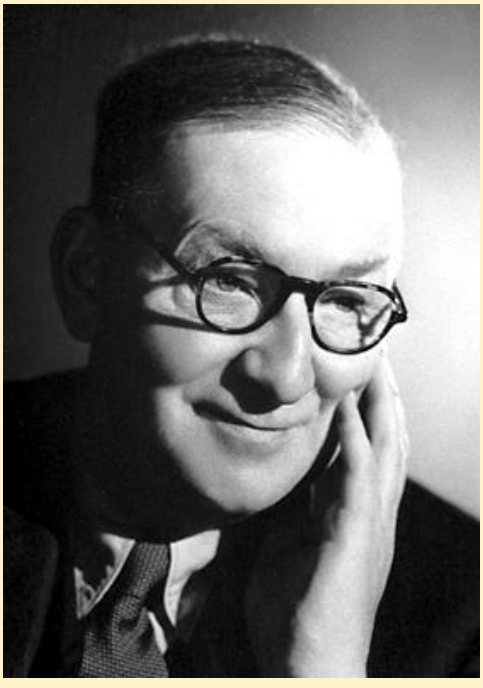
| | | |
|---|---|---|
| |  <br>**Sir George Paget Thomson** | Experimental demonstration of the interference phenomenon in crystals irradiated by electrons |
| **1938** |  <br>**Enrico Fermi** | Disclosure of artificial radioactive elements produced by neutron irradiation |

| | | |
|---|---|---|
| **1939** |  <br>**Ernest Orlando Lawrence** | Invention of the cyclotron |
| **1943** |  <br>**Otto Stern** | Discovery of the magnetic moment of the proton |

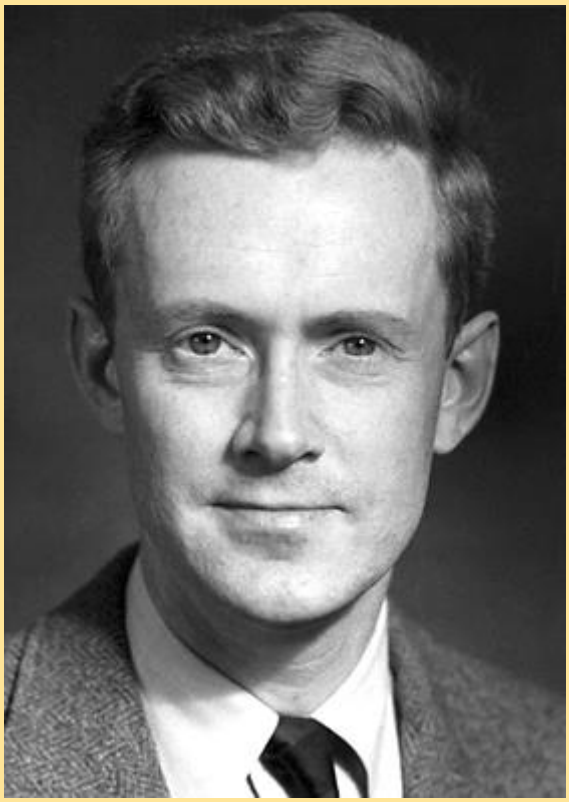
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| **1944** |  <br>**Isidor Isaac Rabi** | Resonance method for registration of various properties of atomic nuclei |
| **1945** |  <br>**Wolfgang Pauli** | Discovery of the exclusion principle of electrons |

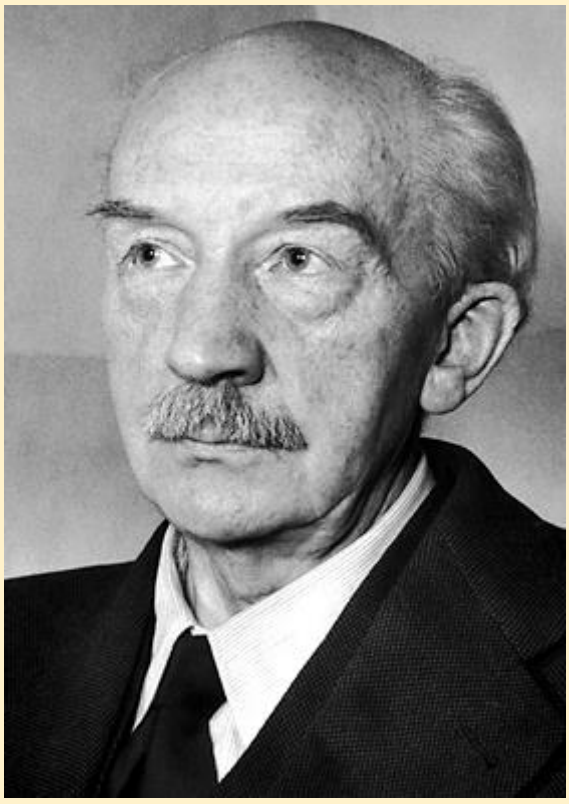
| | | |
|---|---|---|
| **1946** |  <br>**Percy Williams Bridgman** | Discoveries in the domain of high-pressure physics |
| **1947** |  <br>**Sir Edward Victor Appleton** | Discovery of the Appleton layer in the upper atmosphere |

| | | |
|---|---|---|
| **1948** |  <br>**Patrick M.S. Blackett** | Discoveries in the domain of nuclear physics and cosmic radiation |
| **1949** |  <br>**Yukawa Hideki** | Prediction of the existence of mesons |

| | | |
|---|---|---|
| **1950** |  <br>**Cecil Frank Powell** | Photographic method of studying nuclear processes; discoveries concerning mesons |
| **1951** |  <br>**Sir John Douglas Cockcroft** | Work on transmutation of atomic nuclei by accelerated particles |

| | | |
|---|---|---|
| |  <br>**Ernest Thomas Sinton Walton** | Work on transmutation of atomic nuclei by accelerated particles |
| **1952** |  <br>**Felix Bloch** | Discovery of nuclear magnetic resonance in solids |

| | | |
|---|---|---|
| |  <br>**E.M. Purcell** | Discovery of nuclear magnetic resonance<br>in solids |
| **1953** |  <br>**Frits Zernike** | Method of phase-contrast microscopy |

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|---|---|---|
| **1954** |  <br>**Max Born** | Statistical studies of atomic wave functions |
| |  <br>**Walther Bothe** | Invention of the coincidence method |

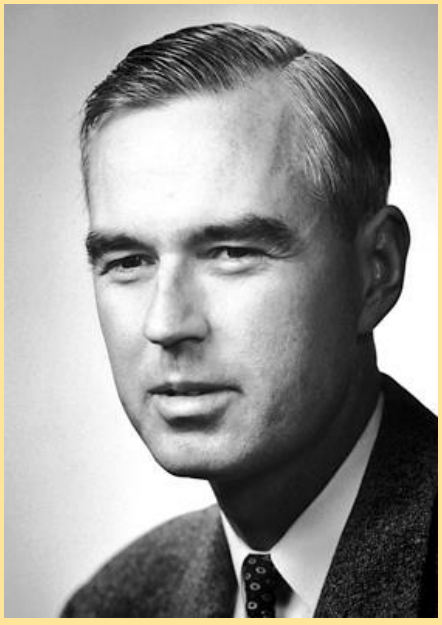
**1955**



**Polykarp Kusch**

Measurement of the magnetic moment of the electron





**Willis Eugene Lamb, Jr.**

Discoveries in the hydrogen spectrum



**1956**



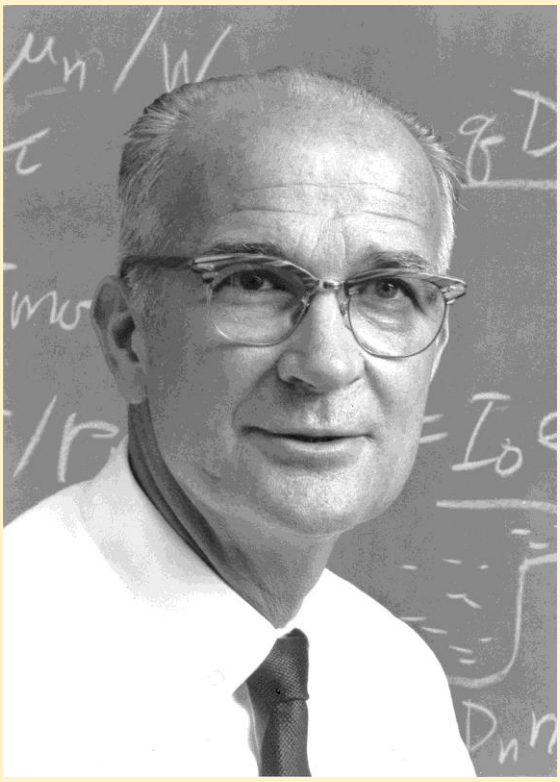
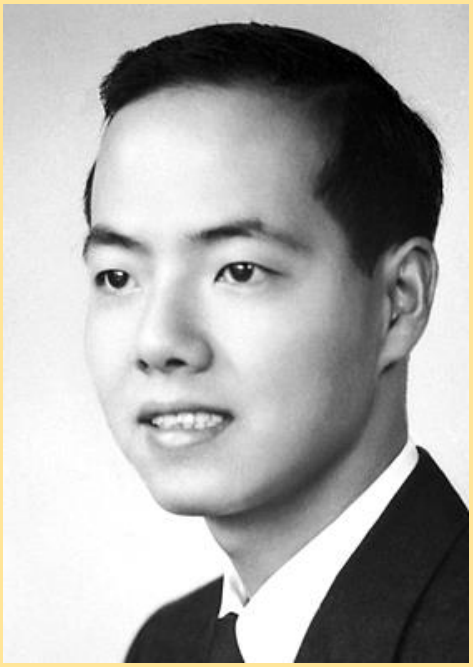
**John Bardeen**

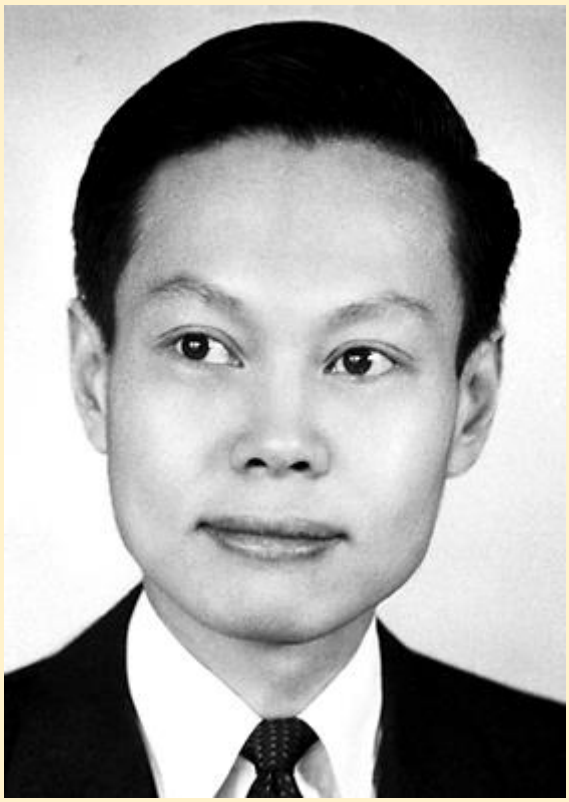
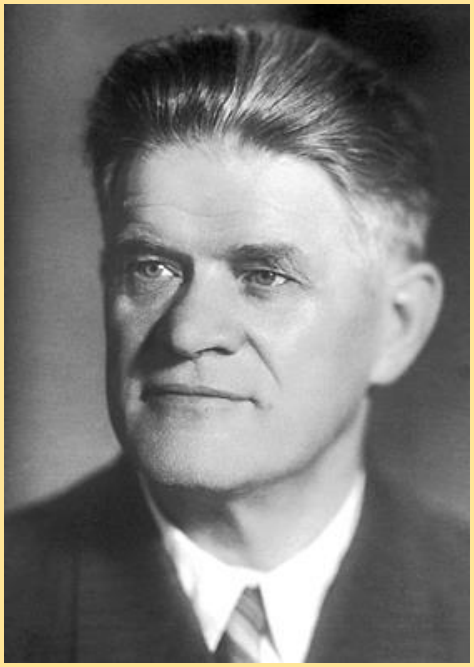
Investigations on semiconductors and invention of the transistor



**Walter H. Brattain**

Investigations on semiconductors and invention of the transistor

| | | |
|---|---|---|
| |  <br>**William B. Shockley** | Investigations on semiconductors and invention of the transistor |
| **1957** |  <br>**Tsung-Dao Lee** | Discovery of violations of the principle of parity |

| | | |
|---|---|---|
| |  <br>**Chen Ning Yang** | Discovery of violations of the principle of parity |
| **1958** |  <br>**Pavel Alekseyevich Cherenkov** | Discovery and interpretation of the Cherenkov effect |



**Ilya Mikhaylovich Frank**

Discovery and interpretation of the Cherenkov effect

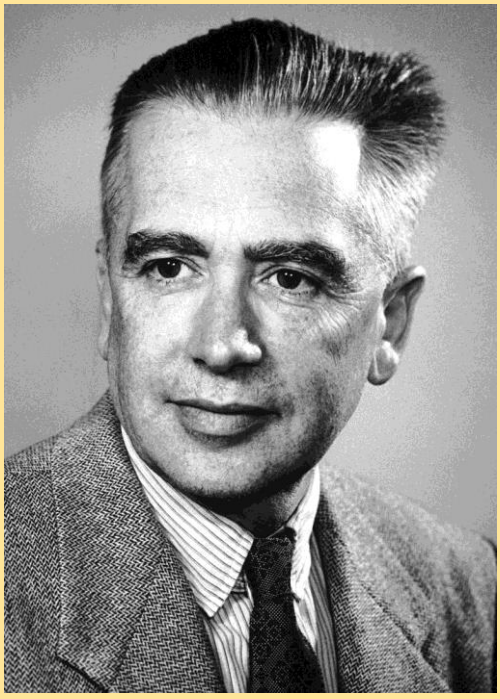




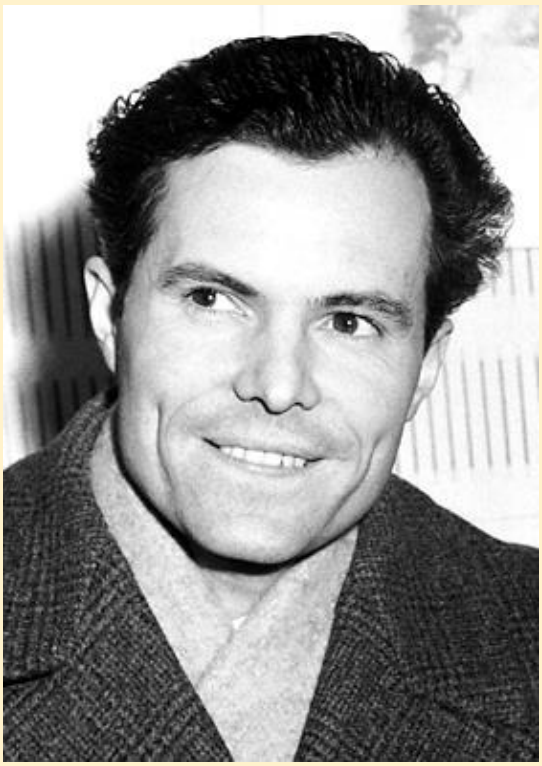
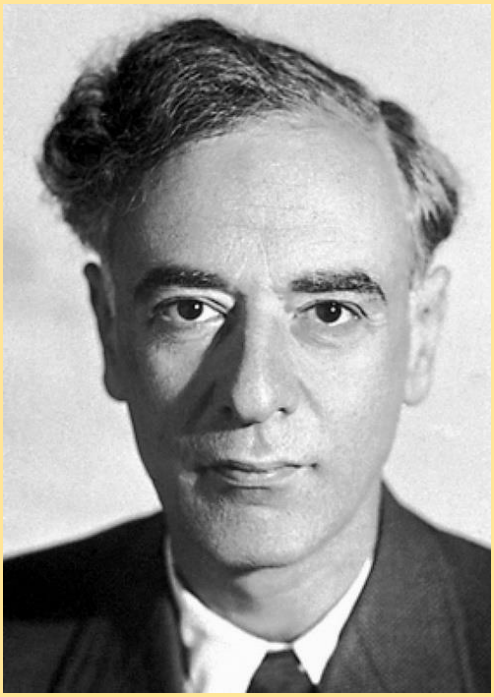
**Igor Yevgenyevich Tamm**

Discovery and interpretation of the Cherenkov effect

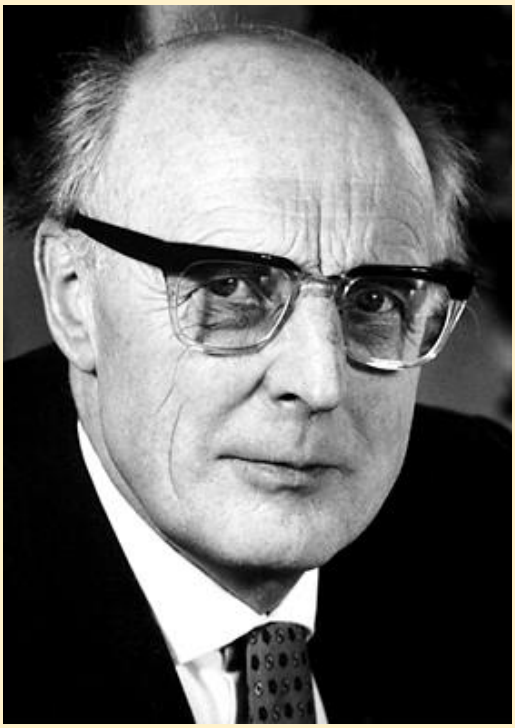


| | | |
|---|---|---|
| **1959** |  <br>**Owen Chamberlain** | Confirmation of the existence of the antiproton |
| |  <br>**Emilio Segrè** | Confirmation of the existence of the antiproton |

| | | |
|---|---|---|
| **1960** |  <br>**Donald A. Glaser** | Development of the bubble chamber |
| **1961** |  <br>**Robert Hofstadter** | Determination of the shape and size of atomic nucleons |

| | | |
|---|---|---|
| |  <br>**Rudolf Ludwig Mössbauer** | Discovery of the Mössbauer effect |
| **1962** |  <br>**Lev Davidovich Landau** | Contributions to the understanding of condensed states of matter |

**1963**



**J. Hans D. Jensen**

Development of the shell model theory of the structure of atomic nuclei



**Maria Goeppert Mayer**

Development of the shell model theory of the structure of atomic nuclei

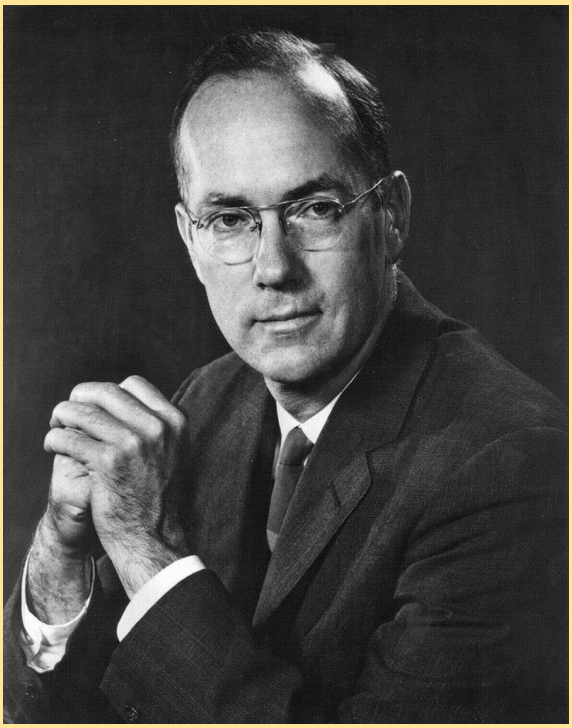
| | | |
|---|---|---|
| |  <br>**Eugene Paul Wigner** | Principles governing interaction of protons and neutrons in the nucleus |
| **1964** |  <br>**Nikolay Gennadiyevich Basov** | Work in quantum electronics leading to construction of instruments based on maser-laser principles |



**Aleksandr Mikhaylovich Prokhorov**

Work in quantum electronics leading to construction of instruments based on maser-laser principles



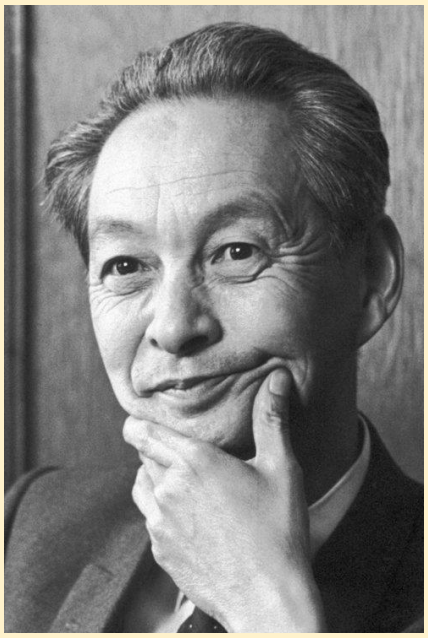
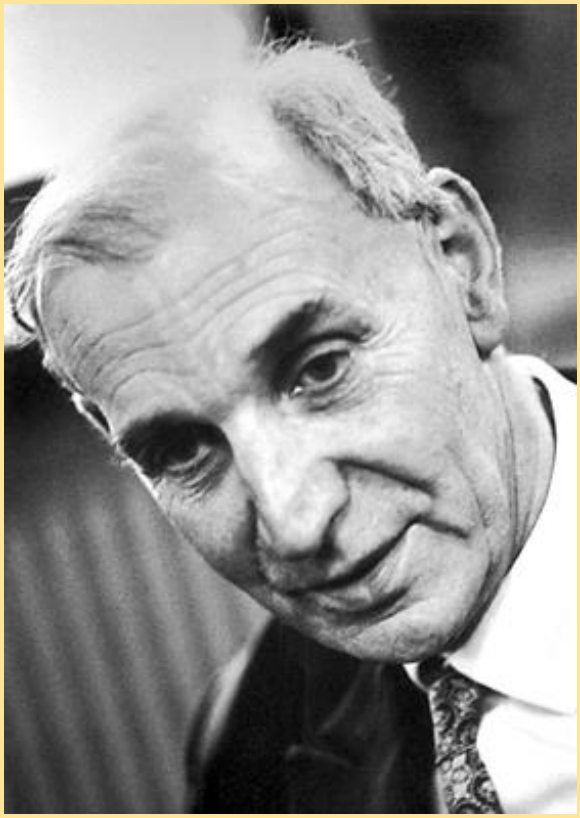


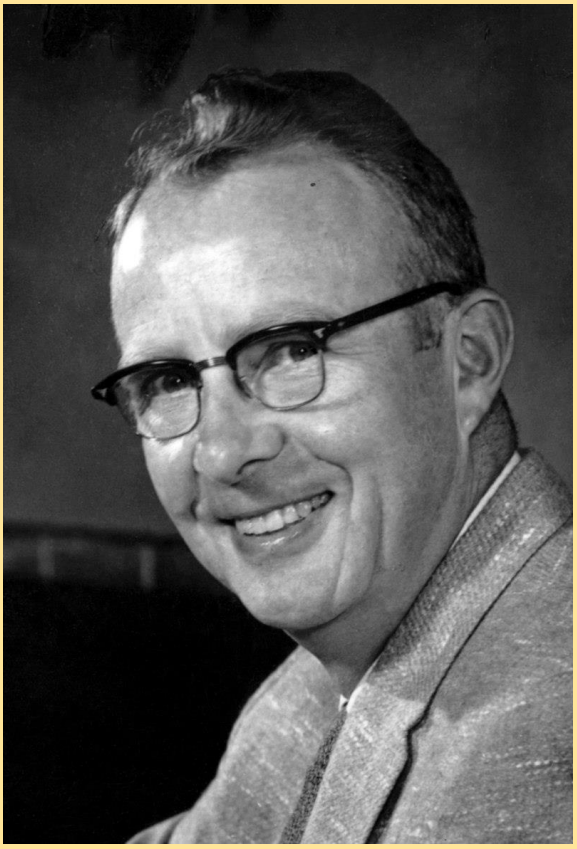
**Charles Hard Townes**

Work in quantum electronics leading to construction of instruments based on maser-laser principles

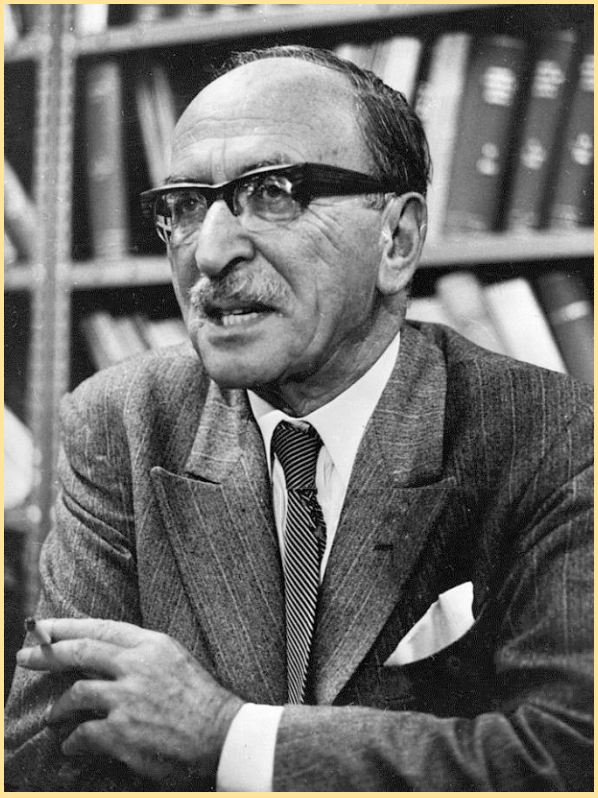


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| **1965** |  <br>**Richard P. Feynman** | Basic principles of quantum electrodynamics |
| |  <br>**Julian Seymour Schwinger** | Basic principles of quantum electrodynamics |

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|---|---|---|
| |  <br>**Shinichiro Tomonaga** | Basic principles of quantum electrodynamics |
| **1966** |  <br>**Alfred Kastler** | Discovery of optical methods for studying Hertzian resonances in atoms |

| | | |
|---|---|---|
| **1967** |  <br>**Hans Albrecht Bethe** | Discoveries concerning the energy production of stars |
| **1968** |  <br>**Luis W. Alvarez** | Work with elementary particles, discovery of resonance states |

| | | |
|---|---|---|
| **1969** |  <br>**Murray Gell-Mann** | Classification of elementary particles and their interactions |
| **1970** |  <br>**Hannes Alfvén** | Work in magnetohydrodynamics with fruitful applications in different parts of plasma physics |

| | | |
|---|---|---|
| |  <br>**Louis Néel** | Work in antiferromagnetism and ferrimagnetism which have led to important applications in solid state physics |
| **1971** |  <br>Dennis Gabor | Invention of holography |

**1972**



**John Bardeen**

Development of the theory of superconductivity



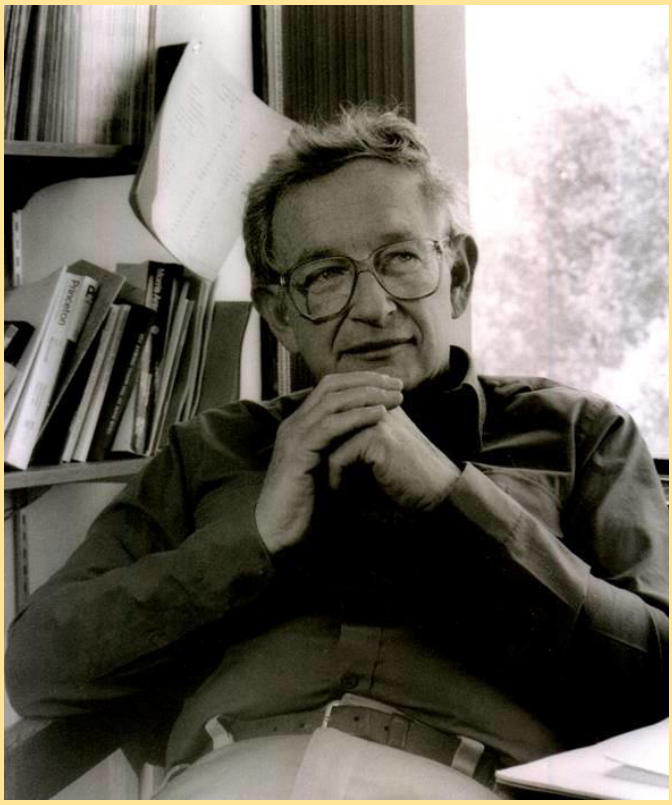
**Leon N. Cooper**

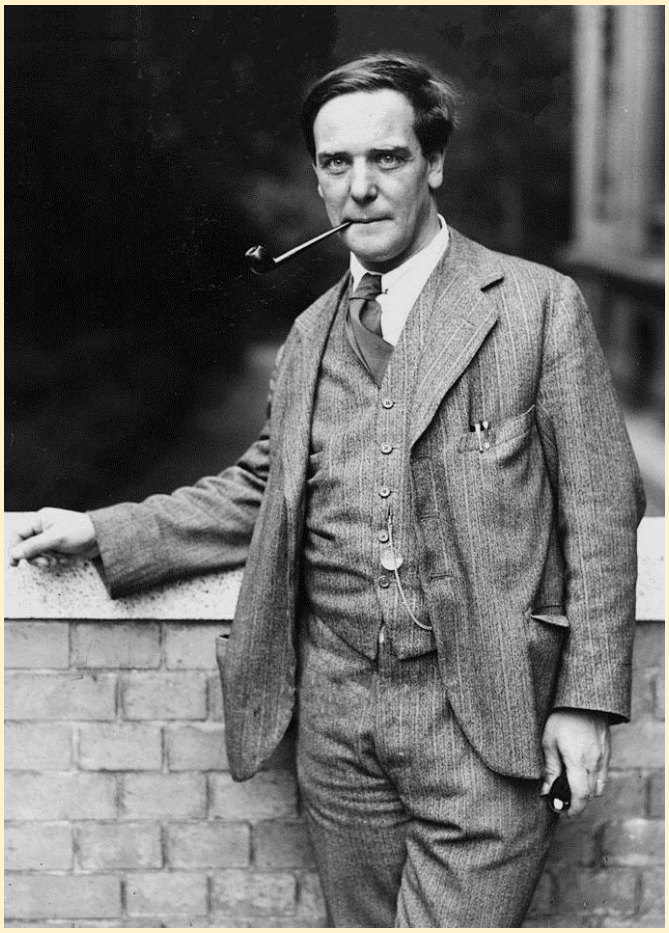
Development of the theory of superconductivity

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|---|---|---|
| |  <br>**John Robert Schrieffer** | Development of the theory of superconductivity |
| **1973** |  <br>**Leo Esaki** | Experimental discoveries regarding tunneling phenomena in semiconductors and superconductors |
| | **Ivar Giaever** | Experimental discoveries regarding tunneling phenomena in semiconductors and superconductors |

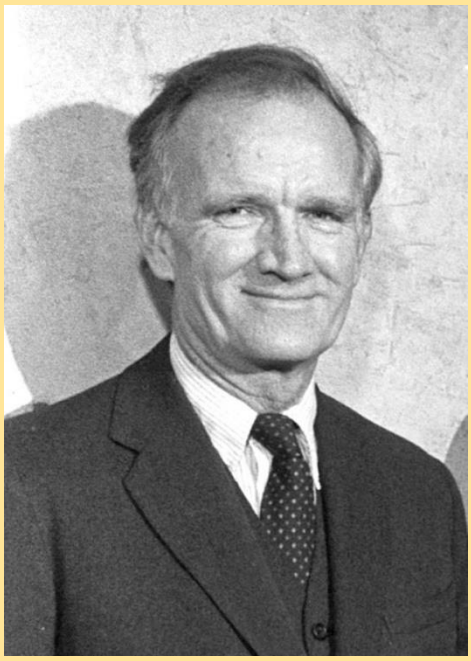
| | | |
|---|---|---|
| | **Brian D. Josephson** | Discovery of the Josephson effect |
| **1974** | **Antony Hewish** | Work in radio astronomy |
| | **Sir Martin Ryle** | Work in radio astronomy |
| **1975** |  **Aage N. Bohr** | Work on the atomic nucleus that paved the way for nuclear fusion |

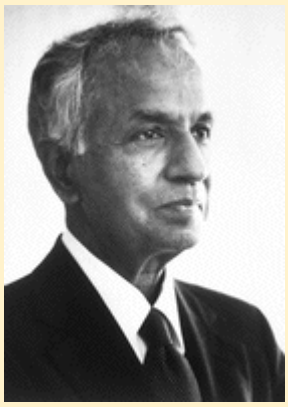
| | | |
|---|---|---|
| | **Ben R. Mottelson** | Work on the atomic nucleus that paved the way for nuclear fusion |
| |  **James Rainwater** | Work on the atomic nucleus that paved the way for nuclear fusion |
| **1976** |  **Burton Richter** | Discovery of a new class of elementary particles (psi, or J) |

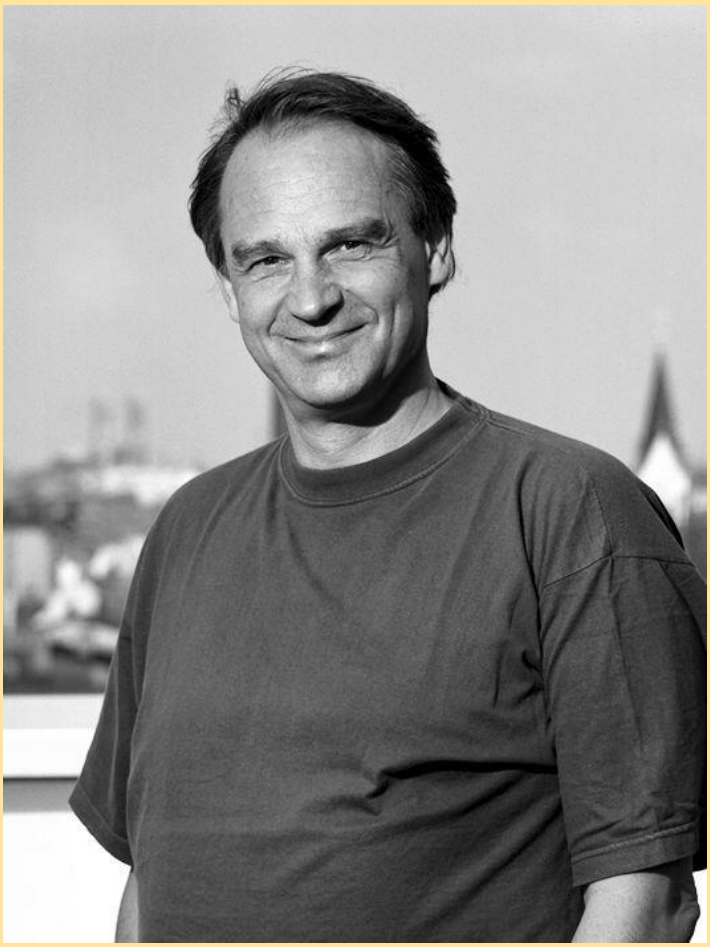
| | | |
|---|---|---|
| | **Samuel C.C. Ting** | Discovery of a new class of elementary particles (psi, or J) |
| **1977** |  **Philip W. Anderson** | Contributions to understanding the behaviour of electrons in magnetic, noncrystalline solids |
| | **Sir Nevill F. Mott** | Contributions to understanding the behaviour of electrons in magnetic, noncrystalline solids |
| | **John H. Van Vleck** | Contributions to understanding the behaviour of electrons in magnetic, noncrystalline solids |

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|---|---|---|
| **1978** |  <br>**Pyotr Leonidovich Kapitsa** | Invention and application of a helium liquefier |
| | **Arno Penzias** | Discovery of cosmic microwave background radiation, providing support for the big-bang theory |
| | **Robert Woodrow Wilson** | Discovery of cosmic microwave background radiation, providing support for the big-bang theory |

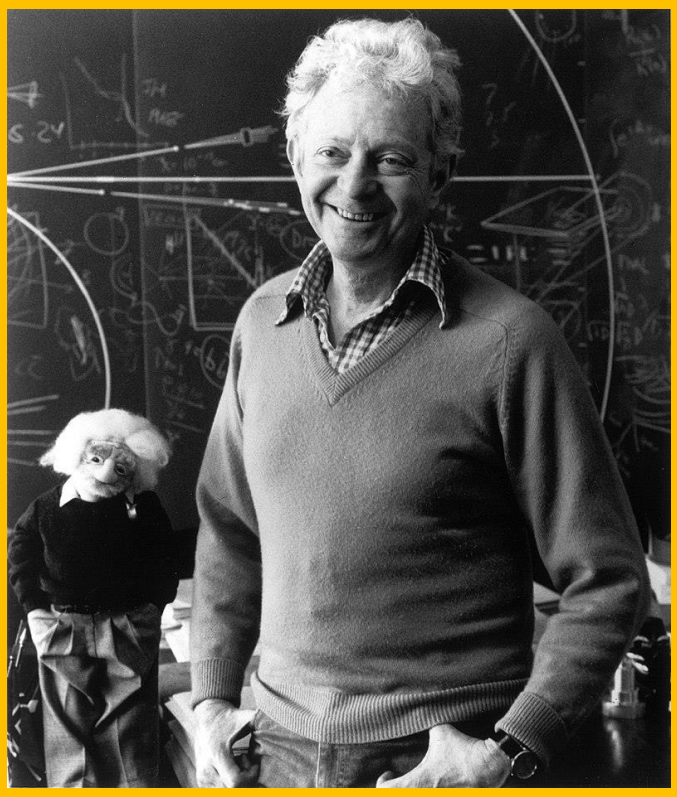
| | | |
|---|---|---|
| **1979** | **Sheldon Lee Glashow**  | Unification of electromagnetism and the weak interactions of subatomic particles |
| | **Abdus Salam**  | Unification of electromagnetism and the weak interactions of subatomic particles |
| | **Steven Weinberg**  | Unification of electromagnetism and the weak interactions of subatomic particles |
| **1980** | **James Watson Cronin**  | Demonstration of simultaneous violation of both charge-conjugation and parity-inversion symmetries |

| | | |
|---|---|---|
| |  <br>Val Logsdon Fitch | Demonstration of simultaneous violation of both charge-conjugation and parity-inversion symmetries |
| **1981** | **Nicolaas Bloembergen** | Applications of lasers in spectroscopy |
| | **Arthur Leonard Schawlow** | Applications of lasers in spectroscopy |
| | **Kai Manne Börje Siegbahn** | Electron spectroscopy for chemical analysis |
| **1982** | **Kenneth Geddes Wilson** | Analysis of continuous phase transitions |

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|---|---|---|
| **1983** |  <br>**Subrahmanyan Chandrasekhar** | Contributions to understanding the evolution and devolution of stars |
| | **William A. Fowler** | Contributions to understanding the evolution and devolution of stars |
| **1984** | **Simon van der Meer** | Discovery of subatomic particles W and Z, which supports the electroweak theory |
| | **Carlo Rubbia** | Discovery of subatomic particles W and Z, which supports the electroweak theory |
| **1985** | **Klaus von Klitzing** | Discovery of the quantized Hall effect |

| | | |
|---|---|---|
| **1986** |  <br>**Gerd Binnig** | Development of electron microscopes |
| | **Heinrich Rohrer** | Development of electron microscopes |
| | **Ernst Ruska** | Development of electron microscopes |

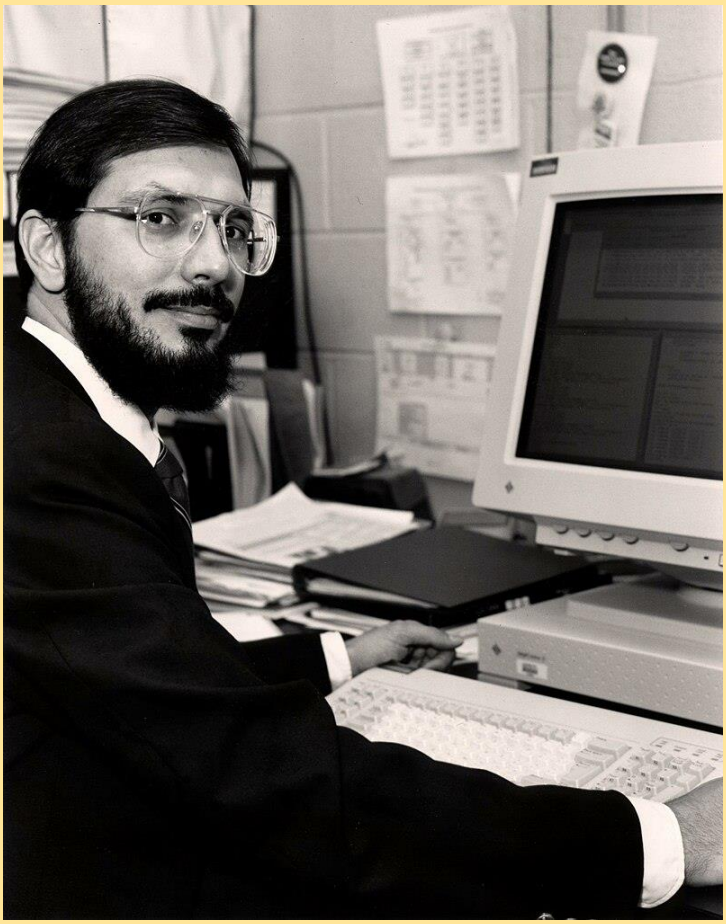
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| **1987** |  <br>**J. Georg Bednorz** | Discovery of new superconducting materials |
| | **Karl Alexander Müller** | Discovery of new superconducting materials |

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|---|---|---|
| **1988** |  <br>**Leon Max Lederman** | Research in subatomic particles |
| | **Melvin Schwartz** | Research in subatomic particles |
| | **Jack Steinberger** | Research in subatomic particles |
| **1989** | **Hans Georg Dehmelt** | Development of methods to isolate atoms and subatomic particles for study |
| | **Wolfgang Paul** | Development of methods to isolate atoms and subatomic particles for study |
| | **Norman Foster Ramsey** | Development of the atomic clock |

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|---|---|---|
| **1990** | **Jerome Isaac Friedman** | Pioneering investigations concerning deep inelastic scattering of electrons on protons and bound neutrons, which have been of essential importance for the development of the quark model in particle physics |
| | **Henry Way Kendall** | Pioneering investigations concerning deep inelastic scattering of electrons on protons and bound neutrons, which have been of essential importance for the development of the quark model in particle physics |



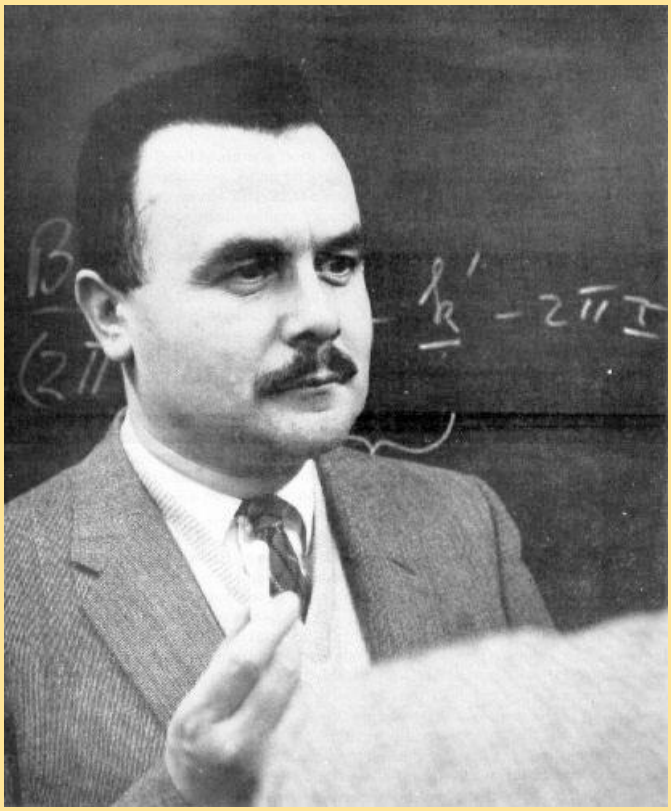
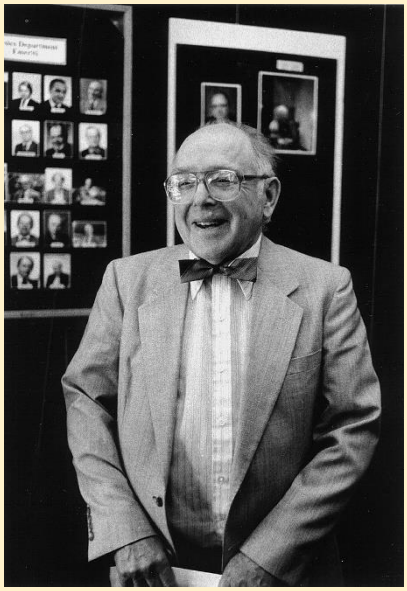
| | | |
|---|---|---|
| |  <br>**Richard E. Taylor** | Pioneering investigations concerning deep inelastic scattering of electrons on protons and bound neutrons, which have been of essential importance for the development of the quark model in particle physics |
| **1991** | **Pierre-Gilles de Gennes** | Discovery of general rules for behaviour of molecules |
| **1992** | **Georges Charpak** | Invention of a detector that traces subatomic particles |

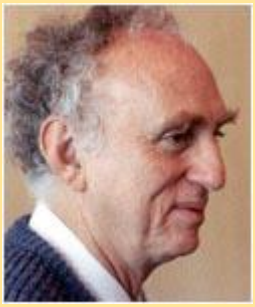
| | | |
|---|---|---|
| **1993** |  | Identifying binary pulsars |
| | **Russell Alan Hulse** | |
| | **Joseph H. Taylor, Jr.** | Identifying binary pulsars |

"If I have a thousand ideas and only one turns out to be good, I am satisfied."

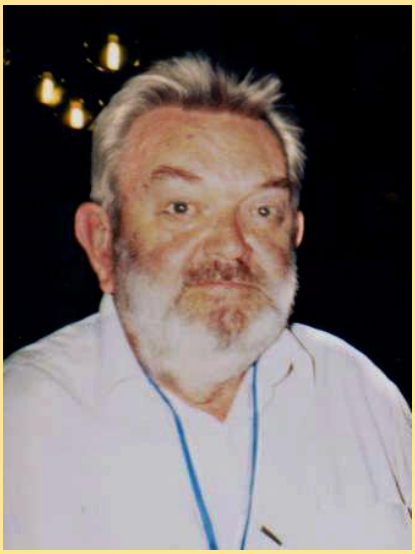
**– Alfred Nobel**

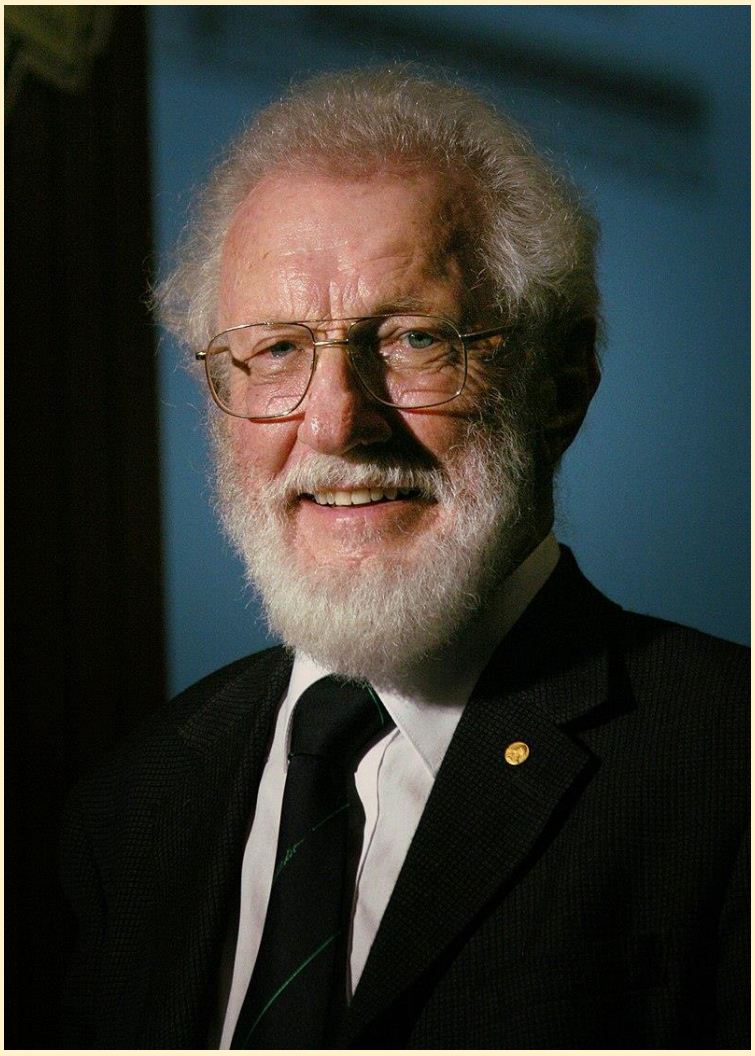


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|---|---|---|
| **1994** |  <br>**Bertram N. Brockhouse** | Development of neutron-scattering techniques |
| |  <br>**Clifford G. Shull** | Development of neutron-scattering techniques |

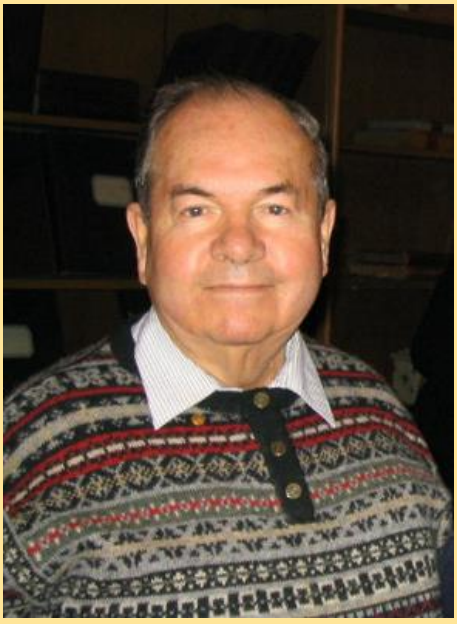
| | | |
|---|---|---|
| **1995** |  <br>**Martin Lewis Perl** | Discovery of the tau subatomic particle |
| |  <br>**Frederick Reines** | Discovery of the neutrino |
| **1996** | **David M. Lee** | Discovery of superfluidity in the isotope helium-3 |

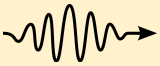
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|---|---|---|
| |  <br>**Douglas D. Osheroff** | Discovery of superfluidity in the isotope helium-3 |
| | **Robert C. Richardson** | Discovery of superfluidity in the isotope helium-3 |
| **1997** | **Steven Chu** | Process of trapping atoms with laser cooling |
| | **Claude Cohen-Tannoudji** | Process of trapping atoms with laser cooling |
| | **William D. Phillips** | Process of trapping atoms with laser cooling |

| | | |
|---|---|---|
| **1998** | **Robert B. Laughlin** | Discovery of a new form of quantum fluid with fractionally charged excitations |
| | **Horst L. Störmer** | Discovery of a new form of quantum fluid with fractionally charged excitations |
| | **Daniel C. Tsui** | Discovery of a new form of quantum fluid with fractionally charged excitations |
| **1999** | **Gerardus 't Hooft** | Study of the quantum structure of electroweak interactions |
| |  **Martinus J.G. Veltman** | Study of the quantum structure of electroweak interactions |
| **2000** | **Zhores I. Alferov** | Development of fast semiconductors for use in microelectronics |

| | | |
|---|---|---|
| | **Jack S. Kilby** | Development of the integrated circuit (microchip) |
| |  **Herbert Kroemer** | Development of fast semiconductors for use in microelectronics |
| **2001** | **Eric A. Cornell** | Achievement of Bose-Einstein condensation in dilute gases of alkali atoms; early fundamental studies of the properties of the condensates |

| | | |
|---|---|---|
| | **Wolfgang Ketterle** | Achievement of Bose-Einstein condensation in dilute gases of alkali atoms; early fundamental studies of the properties of the condensates |
| |  **Carl E. Wieman** | Achievement of Bose-Einstein condensation in dilute gases of alkali atoms; early fundamental studies of the properties of the condensates |
| **2002** | **Raymond Davis, Jr.** | Detection of neutrinos |

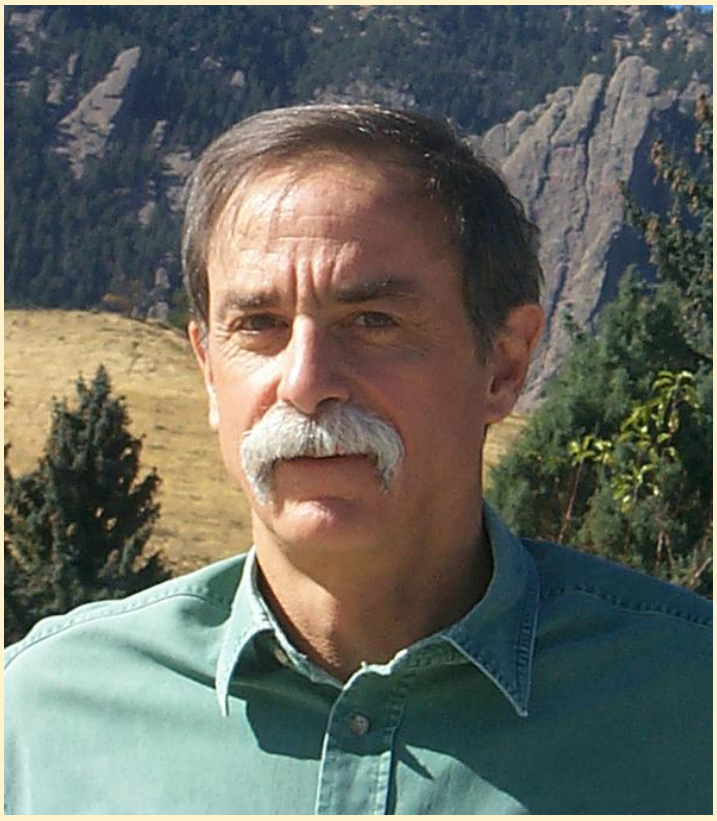
| | | |
|---|---|---|
| |  <br>**Riccardo Giacconi** | Seminal discoveries of cosmic sources of X-rays |
| | **Koshiba Masatoshi** | Detection of neutrinos |
| **2003** |  <br>**Alexei A. Abrikosov** | Discoveries regarding superconductivity and superfluidity at very low temperatures |

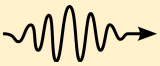
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|---|---|---|
| | **Vitaly L. Ginzburg**  | Discoveries regarding superconductivity and superfluidity at very low temperatures |
| | **Anthony J. Leggett**  | Discoveries regarding superconductivity and superfluidity at very low temperatures |
| **2004** | **David J. Gross**  | Discovery of asymptotic freedom in the theory of the strong interaction |
| | **H. David Politzer**  | Discovery of asymptotic freedom in the theory of the strong interaction |
| | **Frank Wilczek**  | Discovery of asymptotic freedom in the theory of the strong interaction |
| **2005** | **Roy J. Glauber**  | Contributions to the field of optics |
| | **John L. Hall**  | Contributions to the development of laser spectroscopy |
| | **Theodor W. Hänsch**  | Contributions to the development of laser spectroscopy |

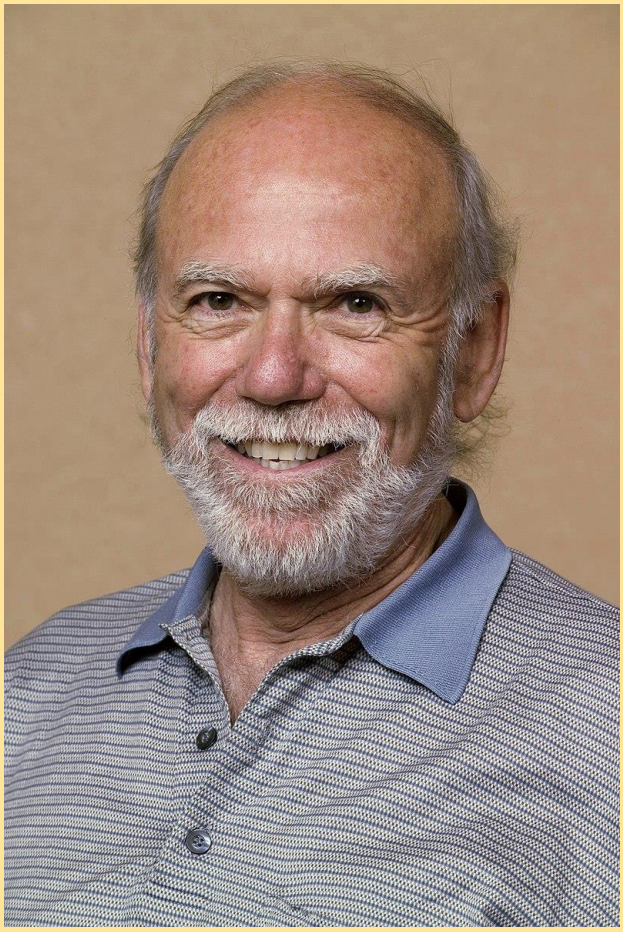
| | | |
|---|---|---|
| **2006** | **John C. Mather** | Discovery of the blackbody form and anisotropy of the cosmic microwave background radiation |
| | **George F. Smoot** | Discovery of the blackbody form and anisotropy of the cosmic microwave background radiation |
| **2007** | **Albert Fert** | Discovery of giant magnetoresistance |
| | **Peter Grünberg** | Discovery of giant magnetoresistance |
| **2008** |  Kobayashi Makoto | Discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature |

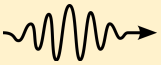
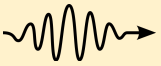
| | | |
|---|---|---|
| |  <br>Maskawa Toshihide | Discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature |
| | **Yoichiro Nambu** | Discovery of the mechanism of spontaneous broken symmetry in subatomic physics |
| **2009** | **Willard Boyle** | Invention of the CCD sensor, an imaging semiconductor circuit |
| | **Charles Kao** | Achievements concerning the transmission of light in fibres for optical communication |
| | **George E. Smith** | Invention of the CCD sensor, an imaging semiconductor circuit |
| **2010** | **Andre Geim** | Experiments regarding the two-dimensional material graphene |

| | | |
|---|---|---|
| | **Konstantin Novoselov** | Experiments regarding the two-dimensional material graphene |
| **2011** |   **Saul Perlmutter** | Discovery of the accelerating expansion of the universe through observations of distant supernovae |
| | **Brian P. Schmidt**  | Discovery of the accelerating expansion of the universe through observations of distant supernovae |
| | **Adam G. Riess**  | Discovery of the accelerating expansion of the universe through observations of distant supernovae |
| **2012** | **Serge Haroche** | Development of methods that enable measuring and |

| | | |
|---|---|---|
| | | manipulation of individual quantum systems |
| |  <br>**David J. Wineland** | Development of methods that enable measuring and manipulation of individual quantum systems |
| **2013** | **François Englert** | Theoretical discovery of a mechanism that contributes to the understanding of the origin of mass of subatomic particles |
| | **Peter Higgs** | Theoretical discovery of a mechanism that contributes to the understanding of the origin of mass of subatomic particles |

| | | |
|---|---|---|
| **2014** | **Akasaki Isamu**  | Invention of efficient blue light-emitting diodes, which has enabled bright and energy-saving white light sources |
| | **Amano Hiroshi**  | Invention of efficient blue light-emitting diodes, which has enabled bright and energy-saving white light sources |
| | **Shuji Nakamura**  | Invention of efficient blue light-emitting diodes, which has enabled bright and energy-saving white light sources |
| **2015** | **Kajita Takaaki**  | Discovery of neutrino oscillations, which show that neutrinos have mass |
| | **Arthur B. McDonald**  | Discovery of neutrino oscillations, which show that neutrinos have mass |
| **2016** | **David Thouless**  | Theoretical discoveries of topological phase transitions and topological phases of matter |
| | **Duncan Haldane**  | Theoretical discoveries of topological phase transitions |

| | | |
|---|---|---|
| | | and topological phases of matter |
| | **Michael Kosterlitz** | Theoretical discoveries of topological phase transitions and topological phases of matter |
| **2017** |  **Barry C. Barish** | Decisive contributions to the Laser Interferometer Gravitational-Wave Observatory detector and the observation of gravitational waves |
| | **Kip S. Thorne** | Decisive contributions to the Laser Interferometer Gravitational-Wave Observatory detector and the |

| | | |
|---|---|---|
| | | observation of gravitational waves |
| | **Rainer Weiss**  | Decisive contributions to the Laser Interferometer Gravitational-Wave Observatory detector and the observation of gravitational waves |
| **2018** | **Arthur Ashkin**  | Invention of optical tweezers and their application to biological systems |
| | **Gérard Mourou**  | Invention of a method of generating high-intensity ultra-short optical pulses |
| | **Donna Strickland**  | invention of a method of generating high-intensity ultra-short optical pulses |
| **2019** | **James Peebles**  | Theoretical discoveries in physical cosmology |
| | **Michel Mayor**  | Discovery of an exoplanet orbiting a solar-type star |
| | **Didier Queloz**  | Discovery of an exoplanet orbiting a solar-type star |

| | | |
|---|---|---|
| **2020** | **Reinhard Genzel**  | Discovery of a supermassive compact object at the centre of the Milky Way Galaxy |
| | **Andrea Ghez**  | Discovery of a supermassive compact object at the centre of the Milky Way Galaxy |
| | **Roger Penrose**  | Discovery that black hole formation is a robust prediction of the general theory of relativity |
| **2021** | **Klaus Hasselmann**  | Development of the foundation for human knowledge of the Earth's climate and how humanity influences it |
| | **Manabe Syukuro**  | Development of the foundation for human knowledge of the Earth's climate and how humanity influences it |
| | **Giorgio Parisi**  | Discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales |
| **2022** | **Alain Aspect**  | Experiments with quantum entanglement that laid the |

| | |
|---|---|
| | foundation for a new era of quantum technology |
| **John F. Clauser** | Experiments with quantum entanglement that laid the foundation for a new era of quantum technology |
| **Anton Zeilinger** | Experiments with quantum entanglement that laid the foundation for a new era of quantum technology |

## A Warning To All Oxygen Breathing Humans

"If You Meet Someone From Another Planet And He Holds Out His Left Hand, Don't Shake It. He Might Be Made Of Antimatter. You Would Both Disappear In A Tremendous Flash Of Light."

**– Stephen Hawking**



✓ The gravitational potential energy, $\mathbf{E_G}$, between two equal masses (each mass is denoted by **M**) separated by a distance r is given by:

$$\mathbf{E_G} = \frac{GM^2}{r}$$

If $\mathbf{E_G} = \frac{Mc^2}{2}$:

$$\frac{Mc^2}{2} = \frac{GM^2}{r}$$

$$r = \frac{2GM}{c^2}$$

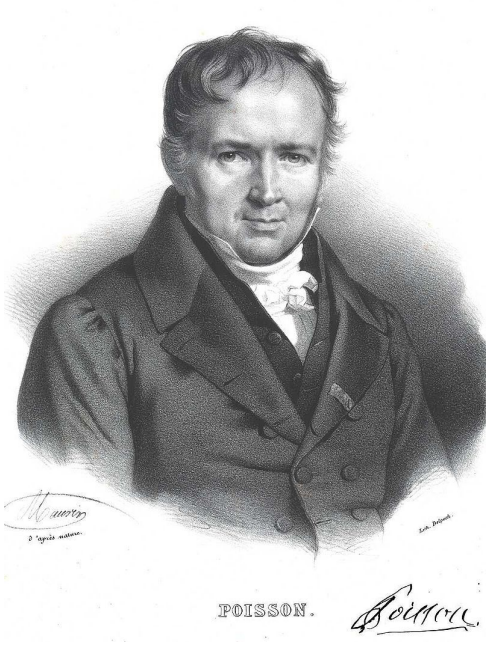
Schwarzschild radius of the mass **M**

The Schwarzschild radius of the mass **M** is the distance of separation between two equal masses (each mass is denoted by **M**) if the gravitational potential energy between two equal masses is equal to $\frac{Mc^2}{2}$.

**Poisson's equation for gravity**

$$\nabla^2\varphi = 4\pi G\rho$$

where $\nabla^2$ is the Laplacian operator, $\boldsymbol{\varphi}$ is the gravitational potential, **G** is the gravitational constant, and ρ is the mass density. This equation describes how the **gravitational potential φ** varies with **position in space**, in response to the **distribution of matter** or **mass density ρ**. It is a fundamental equation in astrophysics and cosmology, used to model the behavior of large-scale structures like galaxies and clusters of galaxies.






**Siméon Denis Poisson** (1781−1840) was a French mathematician, physicist, and engineer. He made significant contributions to a wide range of fields, including probability theory, number theory, celestial mechanics, and electricity and magnetism. **Poisson** was born in **Pithiviers**, France, and studied at the **École Polytechnique** in Paris, where he later became a professor. He was elected to the **French Academy of Sciences** in 1812 and served as its president from 1832 to 1848. He was also a member of the Royal Society in London and the **Berlin Academy of Sciences**. Poisson's most famous contribution is probably his work on probability theory, which includes the development of the **Poisson distribution**, which describes the probability of a given number of events occurring in a fixed interval of time or space, and the **Poisson equation**, which is used to describe the behavior of electric and magnetic fields. In the field of celestial mechanics, **Poisson** made important contributions to the study of the stability of the solar system, and his work on the three-body problem laid the foundation for later work by mathematicians such as **Henri Poincaré**. **Poisson** also made significant contributions to the development of the theory of potential, which is used to study the behavior of fluids and other physical systems. His work on potential theory laid the foundation for later work on the **mathematical theory of elasticity** and the study of fluid flow. Overall, **Poisson** was a highly influential mathematician and physicist, whose work had a profound impact on a wide range of fields.



The smallest object ever observed in visible light has been found in the **Kuiper Belt**, a massive ring of ice debris that circles the outer border of the solar system just beyond **Neptune**. This discovery was made by **NASA's Hubble Space Telescope**. The Hubble discovery of a tiny, 4.2 billion-mile-away object that resembles a needle in a haystack is depicted here by an artist.

✓ **Planck units**

The ultra-high-energy cosmic ray observed in 1991 had a measured energy of about $2.5\times10^{-8}\sqrt{\frac{\hbar c^5}{G}}$

| | |
|---|---|
| **Planck mass** | $m_{Planck} = \sqrt{\frac{\hbar c}{G}} = 2.176434 \times 10^{-8}$ kg |
| **Planck length** | $L_{Planck} = \sqrt{\frac{\hbar G}{c^3}} = 1.616255 \times 10^{-35}$ m |
| **Planck time** | $t_{Planck} = \sqrt{\frac{\hbar G}{c^5}} = 5.391247 \times 10^{-44}$ s |
| **Planck temperature** | $T_{Planck} = \sqrt{\frac{\hbar c^5}{G k_B^2}} = 1.416784 \times 10^{32}$ K |
| **Planck charge** | $q_{Planck} = \sqrt{4\pi\varepsilon_0 \hbar c} = 1.875546 \times 10^{-18}$ C $\approx 11.7e$ |
| **Planck area** | $L^2_{Planck} = \frac{\hbar G}{c^3} = 2.6121 \times 10^{-70}$ m$^2$ |
| **Planck volume** | $L^3_{Planck} = \sqrt{\frac{\hbar^3 G^3}{c^9}} = 4.2217 \times 10^{-105}$ m$^3$ |
| **Planck momentum** | $m_{Planck}c = \frac{\hbar}{L_{Planck}} = \sqrt{\frac{\hbar c^3}{G}} = 6.5249$ kg-m/s |
| **Planck energy** | $m_{Planck}c^2 = \frac{\hbar}{t_{Planck}} = \sqrt{\frac{\hbar c^5}{G}} = 1.9561 \times 10^9$ J |
| **Planck force** | $\frac{m_{Planck}c^2}{L_{Planck}} = \frac{\hbar}{L_{Planck}\, t_{Planck}} = \frac{c^4}{G} = 1.2103 \times 10^{44}$ N |

At which all the fundamental forces are unified.

**Quantum effects of gravity** dominate physical interactions at this time interval.

At this temperature, the wavelength of emitted **thermal radiation** reaches the **Planck length.**

At which quantum effects of gravity become strong.

- It is the gravitational attractive force of two bodies of **one Planck mass** each that are held **one Planck length** apart
- It is the electrostatic attractive or repulsive force of **two Planck units of charges** that are held **one Planck length** apart.

**Events happening at the Planck scale are undetectable with current scientific technology**

| | |
|---|---|
| **Planck power** | $\frac{m_{Planck}c^2}{t_{Planck}} = \frac{\hbar}{t_{Planck}^2} = \frac{c^5}{G} = 3.628 \times 10^{52}\ \text{W}$ |
| **Planck density** | $\frac{m_{Planck}}{L_{Planck}^3} = \frac{c^5}{\hbar G^2} = 5.1550 \times 10^{96}\ \text{kg/m}^3$ |
| **Planck acceleration** | $\frac{c}{t_{Planck}} = \sqrt{\frac{c^7}{\hbar G}} = 5.5608 \times 10^{51}\ \text{m/s}^2$ |
| **Planck frequency** | $\frac{1}{t_{Planck}} = \sqrt{\frac{c^5}{\hbar G}} = 1.8549 \times 10^{43}\ \text{s}^{-1}$ |
| **Planck current** | $\frac{q_{Planck}}{t_{Planck}} = \sqrt{\frac{4\pi\varepsilon_0 c^6}{G}} = 3.479 \times 10^{25}\ \text{A}$ |
| **Planck voltage** | $\frac{m_{Planck}c^2}{q_{Planck}} = \sqrt{\frac{c^4}{4\pi\varepsilon_0 G}} = 1.43 \times 10^{27}\ \text{V}$ |

The density at which the Universe can no longer be described without quantum gravity

✓ For energies approaching or exceeding $\sqrt{\frac{\hbar c^5}{G}} = 1.22 \times 10^{19}\ \text{GeV}$, gravity is problematic and cannot be integrated with quantum mechanics. A new theory of quantum gravity is necessary. Approaches to this problem include:

- **String theory** (point-like particles are replaced by one-dimensional infinitesimal vibrating strings – smaller than atoms, electrons or quarks)
- **M-theory** (The Mother of all theories or Mystery – an 11 dimensional theory in which the weak and strong forces and gravity are unified and to which all the string theories belong)
- **Loop quantum gravity** (a theory of quantum gravity which aims to merge quantum mechanics and general theory of relativity)

A theory that extends general theory of relativity by quantizing spacetime—predicts that black holes evolve into white holes

- **Non-commutative geometry** (a branch of mathematics concerned with a geometric approach to noncommutative algebra)
- **Causal set theory** (an approach to quantum gravity that tries to replace the continuum spacetime structure of general relativity with the spacetime that has the property of discreteness and **causality**)

- The study of how things influence one other
- The study of how causes lead to effects

The idea of quantum foam arises out of Albert Einstein's idea that gravity is caused by the warping and curving of spacetime

**Martin Bojowald**

**A German physicist who developed the application of loop quantum gravity to cosmology**

The incorporation of a standard model into the framework of the quantum gravity

| **Loop Quantum Gravity (quantized space and time)** | **String Theory** |
| --- | --- |
| Does not attempt to unify fundamental interactions | Attempts to unify all four fundamental interactions |
| Approaches the quantum gravity assuming the aspects of general relativity | Approaches the quantum gravity assuming the aspects of quantum theory |
| Does not require a super-symmetry | |

**Grand unification theory**

↓

Fundamental symmetries existed at the beginning of the universe and then broke as the temperature dropped – just as $H_2O$ which looks the same in every direction, freezes into ice, which has distinct directions.

**Expanding matter**

↓

**White hole**

↑

Quantum transition

↓

**Black hole**

↑

**Contracting matter**

The Coulomb constant "$\frac{1}{4\pi\varepsilon_0}$" is a proportionality constant in electrostatics equations. It was named after the French physicist Charles-Augustin de Coulomb who introduced Coulomb's law.

A measure of how much the light from a distant object has been stretched as the universe has expanded

$$(1+ z) = \frac{\text{The scale factor of the universe at the present time}}{\text{The scale factor of the universe at the time the light was emitted from the object}}$$

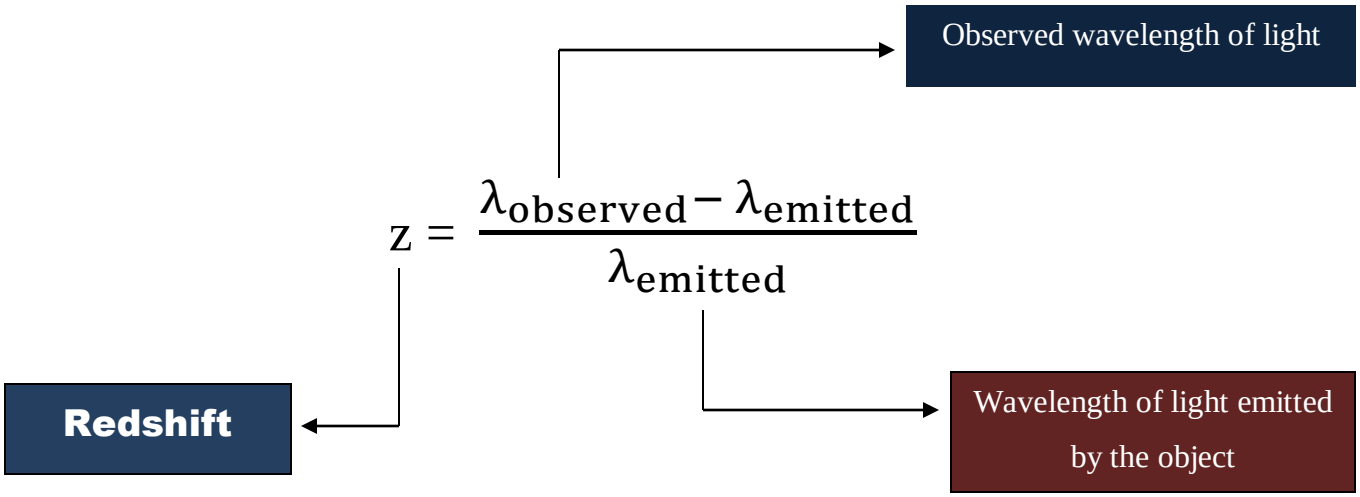
$$(1+ z) = \frac{a_{now}}{a_{then}}$$

For example, suppose we observe a galaxy with a redshift of z = 0.5. This means that the galaxy's light has been stretched by a factor of (1+z) = 1.5 as it traveled to us through the expanding universe. Therefore:

$$1.5 = \frac{3}{2} = \frac{a_{now}}{a_{then}}$$

$$a_{then} = \frac{2}{3} a_{now}$$

The scale factor of the universe at the time the light was emitted was two-thirds of what it is now.




For example, if a galaxy emits light at a wavelength of 500 nm (nanometers) and we observe the light at a wavelength of 550 nm, the **redshift** can be calculated as follows:

$$z = \frac{(550\ \text{nm} - 500\ \text{nm})}{500\ \text{nm}} = 0.1$$

This means that the star is moving away from the Earth with a velocity that is 10% of the speed of light.

$$z = \frac{\lambda_{emitted} - \lambda_{observed}}{\lambda_{observed}}$$

**Blueshift**

For example, if a star emits light with a wavelength of 500 nm, but the light is observed on Earth with a wavelength of 480 nm, the **blueshift** can be calculated as follows:

$$z = \frac{(500\ \text{nm} - 480\ \text{nm})}{480\ \text{nm}} = 0.0417$$

This means that the star is moving towards the Earth with a velocity that is 4.17% of the speed of light

$$T \propto \frac{1}{a}$$

$$(1+ z) = \frac{T_{then}}{T_{now}}$$

Temperature of the radiation at the present time

$$T_{then} = T_{now}\ (1+z)$$

Temperature of the radiation at the time the radiation was emitted from the object

For example, suppose:

$$z = 0.5$$

$$T_{now} = 5000\ K$$

$$T_{then} = 5000\ K\ (1+ 0.5)$$

$$T_{then} = 7500\ K$$

So, the radiation emitted by the object had a temperature of 75000 K when it was emitted, but due to the expansion of the universe, the wavelength of this radiation has been stretched, causing it to appear cooler (i.e., with a lower temperature) to us today. The redshift of z=0.5 tells us that the universe has expanded by a factor of 1+z = 1.5 since the radiation was emitted.

**Radiation era:**

Scale factor of the universe proportional to $(\text{time})^{\frac{1}{2}}$

Temperature proportional to $\frac{1}{(\text{time})^{\frac{1}{2}}}$

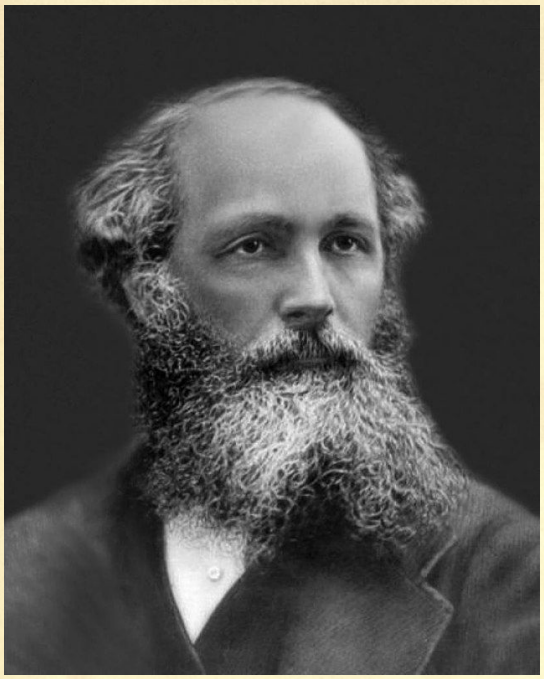
**Matter era:**

Scale factor of the universe proportional to $(\text{time})^{\frac{2}{3}}$

Temperature proportional to $\frac{1}{(\text{time})^{\frac{2}{3}}}$



✓ **A painting of Copernicus looking up at the stars**



J. Clerk Maxwell

Clarendon Press Series

# A TREATISE

ON

# ELECTRICITY AND MAGNETISM

BY

JAMES CLERK MAXWELL, M.A.

LLD. EDIN., F.R.SS. LONDON AND EDINBURGH

HONORARY FELLOW OF TRINITY COLLEGE,

AND PROFESSOR OF EXPERIMENTAL PHYSICS

IN THE UNIVERSITY OF CAMBRIDGE

VOL. I

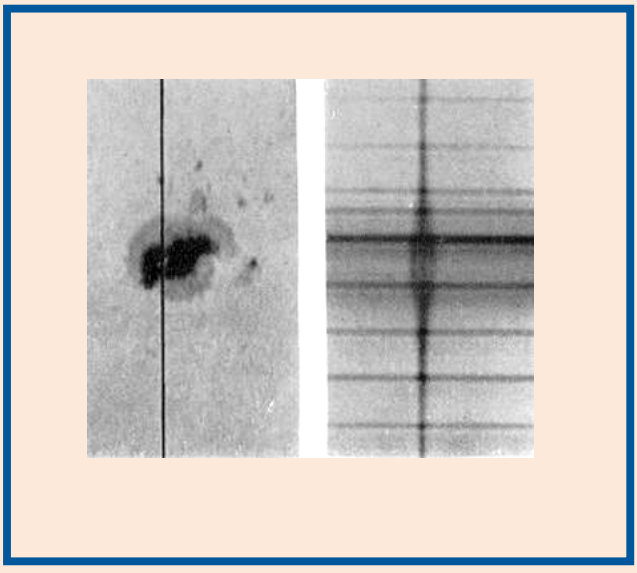
Oxford

AT THE CLARENDON PRESS

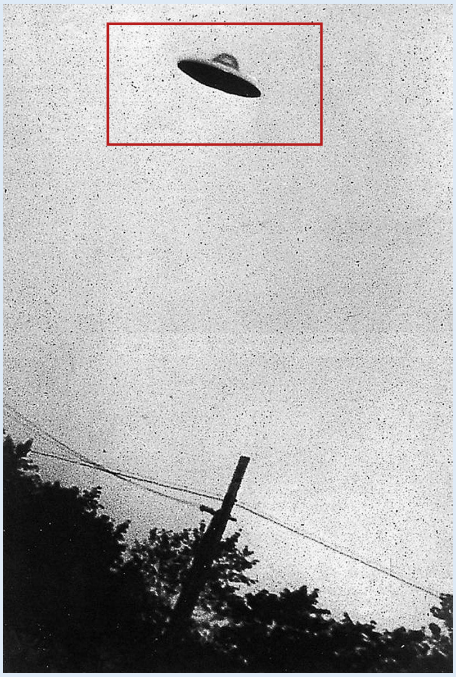
1873

[All rights reserved]

The famous two-volume publication **"A Treatise on Electricity and Magnetism"** was authored by Scottish scientist and mathematician **James Clerk Maxwell**. The book was first published in 1873 and is considered one of the most influential works in the history of physics. **Maxwell's treatise** is divided into four parts. The **first part** deals with electrostatics, including the laws of Coulomb, Gauss, and Faraday, as well as the concepts of potential and capacitance. The **second part** deals with magnetostatics, including the laws of Ampère, the magnetic field of a current, and the force between two currents. The **third part** of the book introduces the concept of electromagnetic fields and their behavior, including **Faraday's law of electromagnetic induction**, **electromagnetic waves**, and the **relationship between electricity and magnetism**. In this section, **Maxwell** also presents his famous set of four equations, known as Maxwell's equations, which describe the behavior of electric and magnetic fields. Finally, the **fourth part** of the book discusses the properties of electromagnetic waves, including their speed and polarization, and the interaction between electromagnetic waves and matter. This section also includes Maxwell's calculation of the speed of light in a vacuum, which led to the conclusion that light is an electromagnetic wave. **Maxwell's "A Treatise on Electricity and Magnetism"** revolutionized the field of electromagnetism and had a profound impact on the development of modern physics. The mathematical formulations and concepts introduced in this book laid the foundation for the field of electrodynamics, and many of **Maxwell's ideas** and equations are still in use today.



Magnetic field of **sunspot** (left) splits absorption line according to **Zeeman Effect** (right).



A picture of a suspected **UFO** taken on July 31, 1952 near Passaic, New Jersey.

## Unidentified flying object (UFO)

Any object or light in the sky that observers cannot recognize as a known aircraft, natural occurrence, or any other familiar object. **UFO sightings** have been reported worldwide and have been the subject of speculation, debate, and scientific investigation for many years. While some UFO sightings have plausible explanations, others remain unexplained or mysterious.



Leased Wire
Associated Press

# Roswell Daily Record

RECORD PHONES
Business Office 2288
News Department
2287

ROSWELL, NEW MEXICO, TUESDAY, JULY 8, 1947

Movies as Usual

GRAND

Claims Army Is Stacking Courts Martial

Indiana Senator Lays Protest Before Patterson

## RAAF Captures Flying Saucer On Ranch in Roswell Region

House Passes Tax Slash by Large Margin

Defeat Amendment By Demos to Remove Many from Rolls

Security Council Paves Way to Talks On Arms Reductions

No Details of Flying Disk Are Revealed

Roswell Hardware Man and Wife Report Disk Seen

Ex-King Carol Weds Mme. Lupescu

Former King Carol of Romania and Mme. Elena Lupescu relax aboard the S. S. America bound for Cuba and Mexico in May, 1941. A member of Carol's household in Rio de Janeiro said the ex-king and his companion for 23 years in exile and exile were recently married at their hotel Copacabana Palace suite. (AP Wirephoto).

Lewes broke and flood waters rolled into the town of Grand Tower, Ill., but while the manager of the movie theater sweeps out the water that has entered the lobby these youngsters are standing in line for tickets for the night's performance. (AP Wirephoto).

Some of Soviet Satellites May Attend Paris Meeting

Roswellians Have Differing Opinions On Flying Saucers

American League Wins All-Star Game

Miners and Operators Sign Highest Wage Pact in History

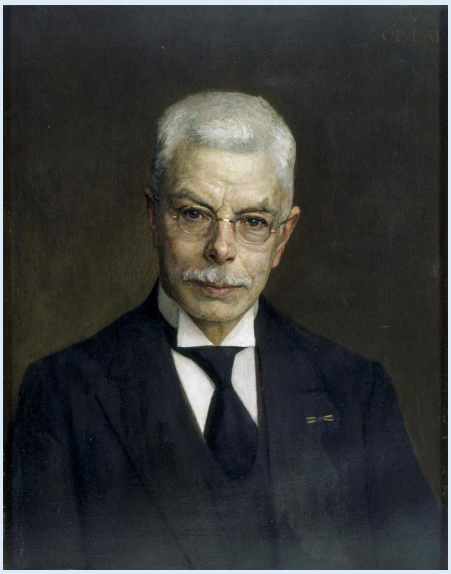
On July 8, 1947, the **Roswell Daily Record** published a report about a **UFO** incident.

# Zeeman Effect

The **Zeeman Effect**, discovered by the Dutch physicist **Pieter Zeeman** in 1896, refers to the splitting of spectral lines of an **atomic spectrum** when exposed to an external magnetic field. During his study of sodium spectral lines in a magnetic field, **Zeeman** observed this phenomenon, which provided experimental proof of the existence of **electron magnetic moments** and confirmed the predictions of the **electromagnetic theory of light**. This pivotal discovery marked a major advancement in atomic physics and served as the basis for numerous subsequent investigations into the interaction between matter and electromagnetic fields. The **Zeeman Effect** causes the energy of spectral lines of an atomic spectrum to shift when an external magnetic field is applied. The **energy shift** (ΔE) of a spectral line due to the **Zeeman Effect** is given by the following equation:

$$\Delta E = g \times \frac{e\hbar}{2m_e} \times m_\ell \times B$$

where: $\frac{e\hbar}{2m_e} = \mu_B$ is the **Bohr magneton** (a physical constant representing the magnetic moment of an electron), B is the applied external magnetic field strength, g is the **Landé g-factor** (a dimensionless quantity that characterizes the magnetic moment of an atom in the presence of an external magnetic field.) and $m_\ell$ is the **Magnetic quantum number** (the quantum number that describes the orientation of the orbital angular momentum of an electron in an atom relative to an external magnetic field).



✓ **Pieter Zeeman**

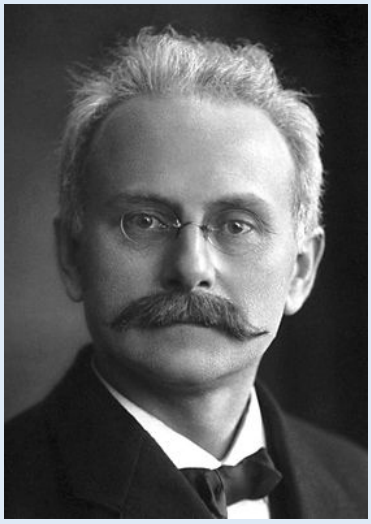


✓ **Einstein visiting Pieter Zeeman in Amsterdam, with his friend Ehrenfest (around 1920).**

The **Stark effect**, observed in 1913 by the German physicist **Johannes Stark** during his investigation of hydrogen's spectral lines in the presence of an external electric field, refers to the phenomenon of the splitting of spectral lines of an atomic spectrum when exposed to an external electric field. This ground-breaking discovery offered experimental proof for the existence of electric dipole moments in atoms and molecules, validating the predictions of the **quantum theory of light**. The discovery of the **Stark effect** marked a pivotal advancement in the progress of atomic and molecular physics, and it holds substantial significance in various fields, including spectroscopy, plasma physics, and astrophysics. The **Stark Effect** causes the energy of spectral lines of an atomic spectrum to shift when an external electric field is applied. The energy shift (ΔE) of a spectral line due to the **Stark Effect** is given by the following equation:

$$\Delta E = \mu \times E$$

where μ is the electric dipole moment of the atom and E is the applied external electric field strength.

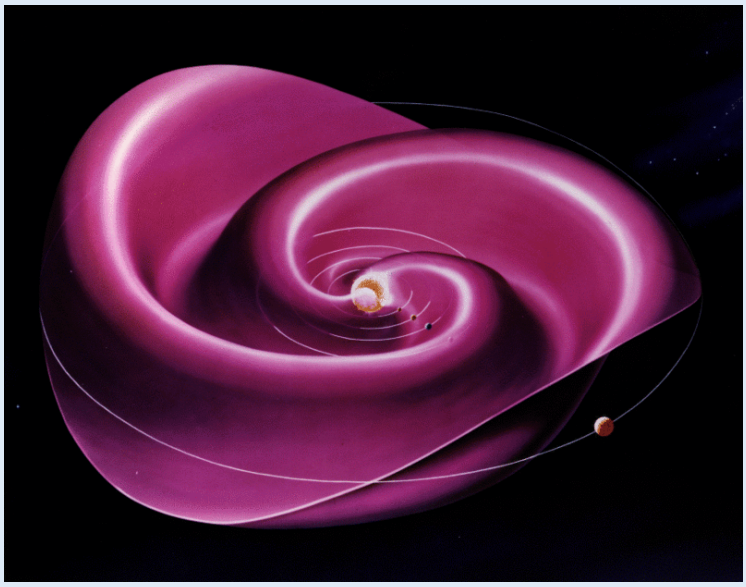


✓ **Johannes Stark**



## ✓ Interplanetary medium

The matter that fills the space between the planets in our solar system.



The **heliospheric current sheet** is a vast, wavy, and dynamic structure that extends throughout the entire solar system. It is a direct result of the influence of the Sun's rotating magnetic field on the plasma (charged particles, mainly electrons and protons) present in the interplanetary medium.

## Interplanetary dust cloud

A vast cloud of cosmic dust that pervades the space between the planets in our solar system.

## Exozodiacal dust

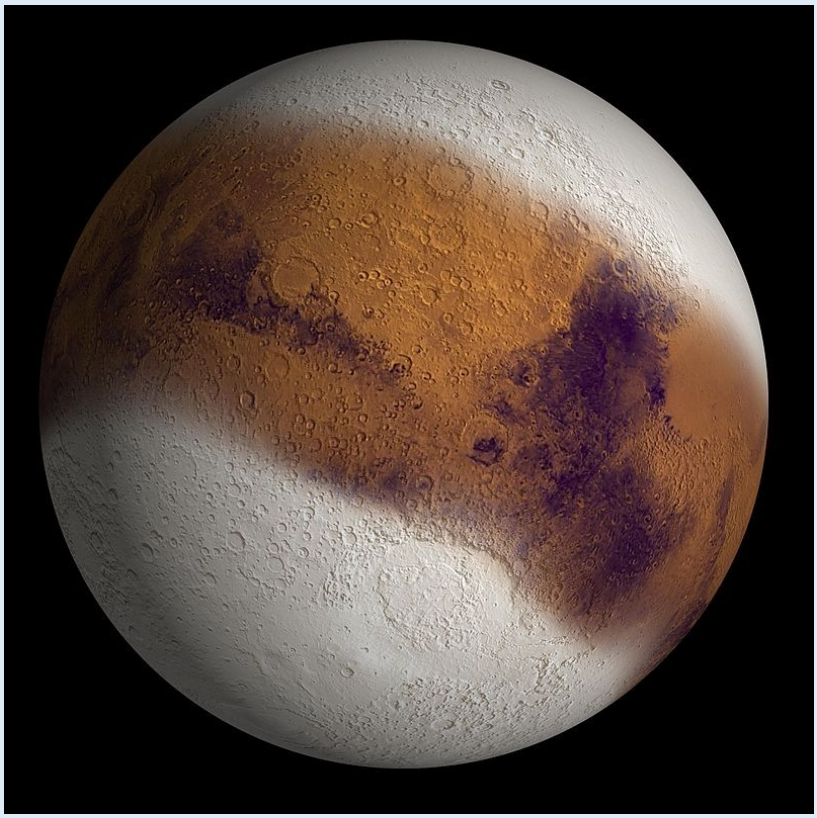
Small Amorphous carbon and silicate particles, typically ranging in size from 1 to 100 micrometers, which populates the plane of extrasolar planetary systems.

## Intergalactic dust

Cosmic dust in between galaxies in intergalactic space.

## The warm-hot intergalactic medium (WHIM)

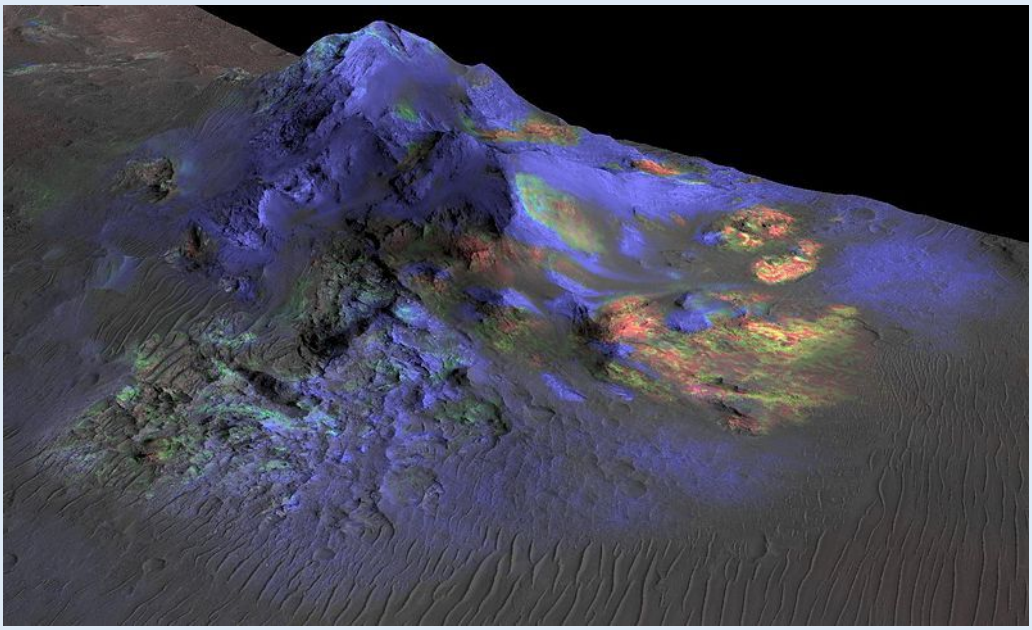
A sparse and diffuse plasma with temperatures ranging from about $10^5$ to $10^7$ Kelvin (K). It is believed to occupy the vast spaces between galaxies in the universe and is considered a crucial reservoir of baryonic matter.



An depiction of what Mars might have looked like during an ice age between 2.1 million and 400,000 years ago, when Mars's axial tilt is believed to have been much larger than today.

# Mars analog habitat

A specially designed environment on Earth that mimics the conditions and challenges that astronauts would face while living and working on Mars. These habitats are constructed to provide a realistic simulation of Martian living conditions, allowing scientists and astronauts to test technologies, conduct experiments, and develop strategies for future manned missions to the Red Planet.



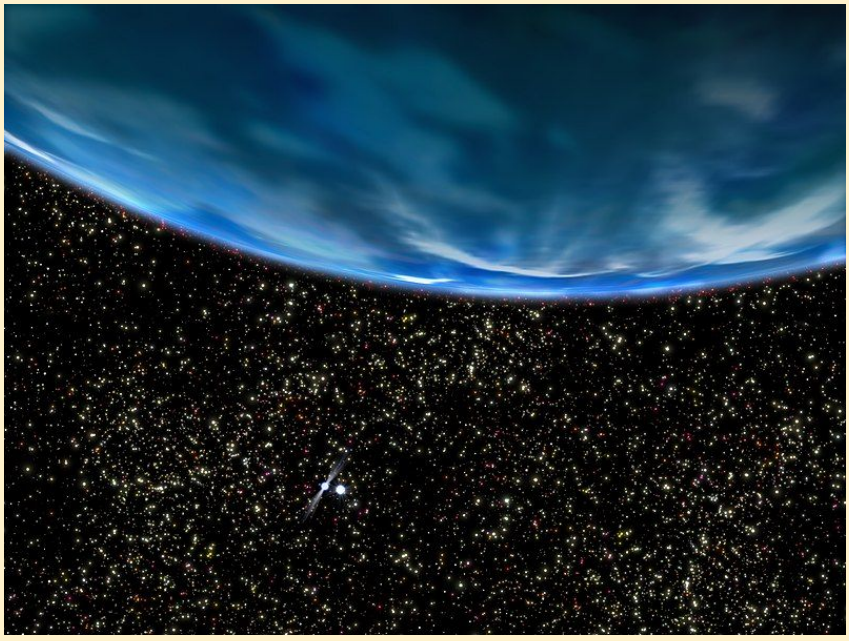
**Alga Crater** is a 19-kilometer-wide crater in the southern hemisphere of Mars. It is thought to have formed about 3.8 billion years ago, when a large asteroid or comet impacted the planet. The impact would have created a great deal of heat, which would have melted the rock and formed impact glass.

## Astrometry

A branch of astronomy that deals with the precise measurement of the positions, motions, and distances of celestial objects. It involves the study of the positions and movements of stars, planets, asteroids, comets, and other celestial bodies in the night sky. **Astrometry** is one of the oldest and fundamental aspects of astronomy, forming the basis for our understanding of the universe's structure and dynamics.

## Circumbinary planet

A planet that orbits two stars instead of one.



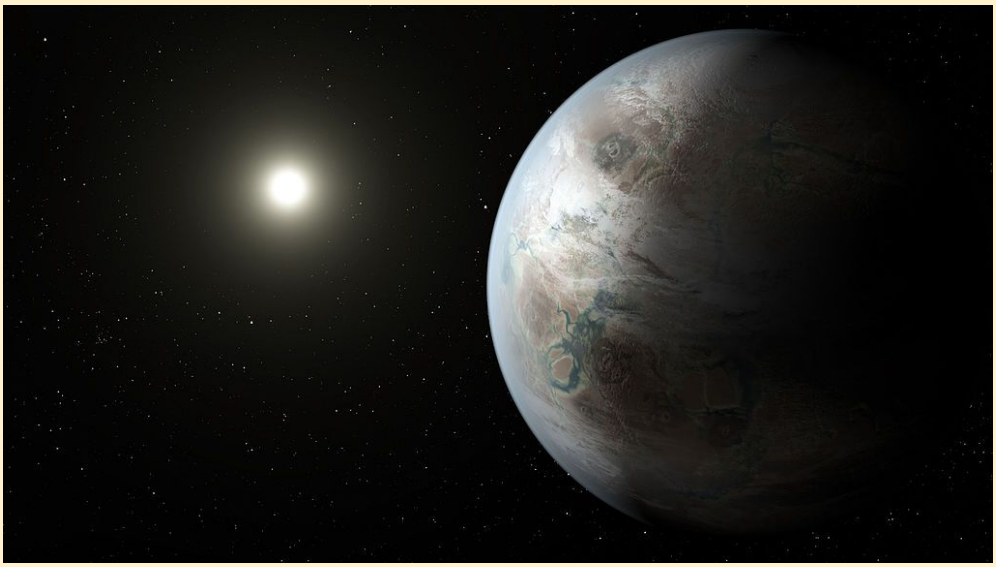
An artistic depiction of the massive planet in orbit around the binary system **PSR B1620-26**, which consists of a pulsar and a white dwarf star. This intriguing binary system is situated within the globular cluster **M4**.

## Circumtriple planet

A planet that orbits three stars instead of one.

## Hills mechanism

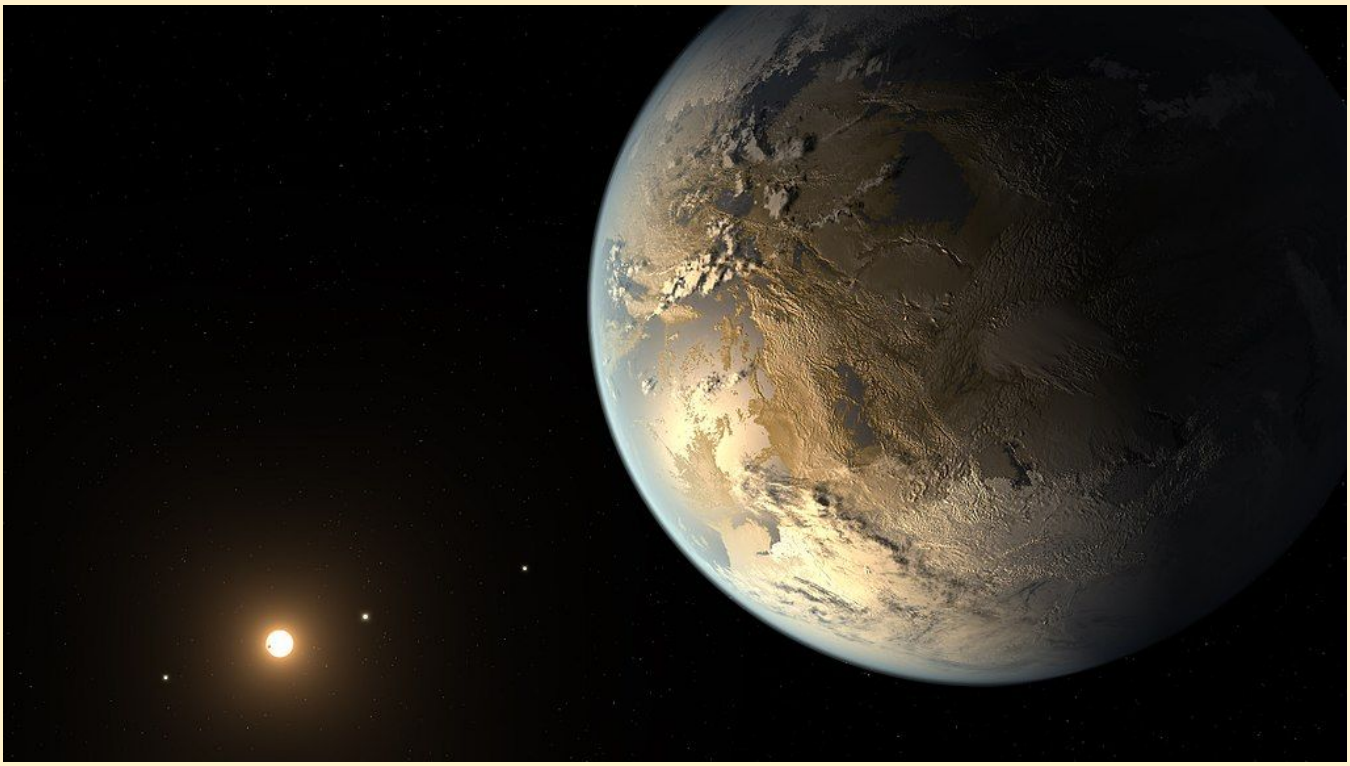
A phenomenon first proposed by astronomer **Jack Hills** in 1988 and later confirmed in 2019, occurs when a binary star system gets disrupted by the gravitational forces of a supermassive black hole. The black hole's enormous tidal forces grab one of the stars in the binary system, causing the star to fall into an orbit around the black hole. Meanwhile, the other star is ejected from the binary system, driven away from the black hole at incredible speeds.



This artistic representation showcases **Kepler-452b**, an intriguing exoplanet that has the potential to support life. It belongs to the category of exoplanets orbiting a yellow dwarf star, much like our own sun.

# Superhabitable planet

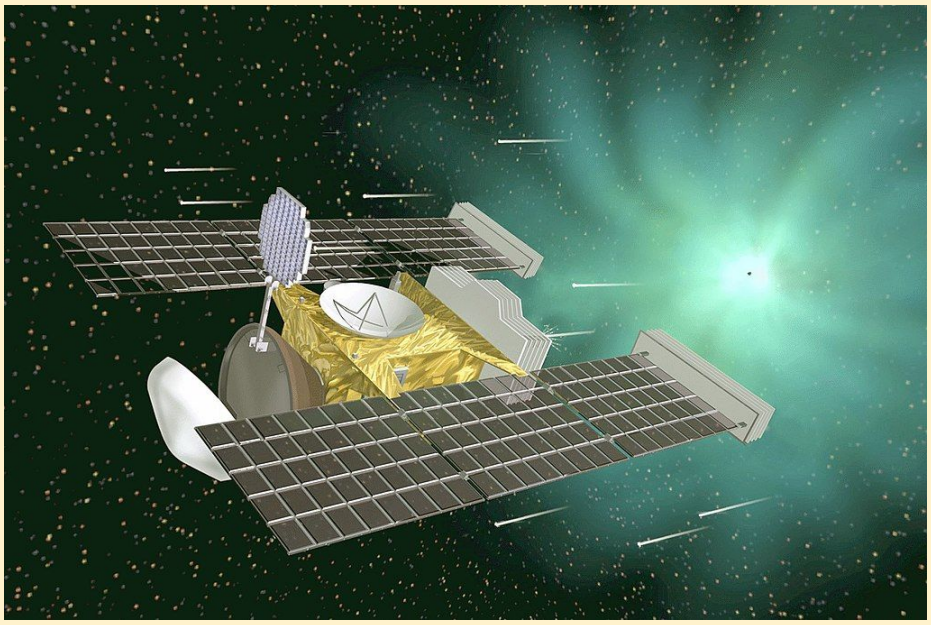
A theoretical category of **exoplanet** or **exomoon** that scientists propose could be even more favourable than Earth for the emergence and evolution of life. These hypothetical celestial bodies possess conditions and features that could potentially provide a more favourable environment for life to thrive.



An artist's impression of **Kepler-186f**, a possible Earth analog, shows a planet that could be very similar to our own. Some superhabitable planets, which are thought to be even more Earth-like than **Kepler-186f**, could also have a similar appearance. These planets may not have any significant differences from Earth, making them potential candidates for life.

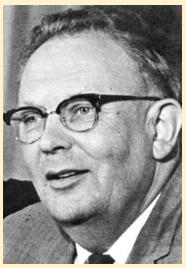
## ✓ Tanpopo mission

A fascinating mission designed to collect cosmic dust in low Earth orbit. Launched by the **Japan Aerospace Exploration Agency** (JAXA), the mission's primary objective was to study the potential for life to exist outside Earth and examine the **panspermia hypothesis**.



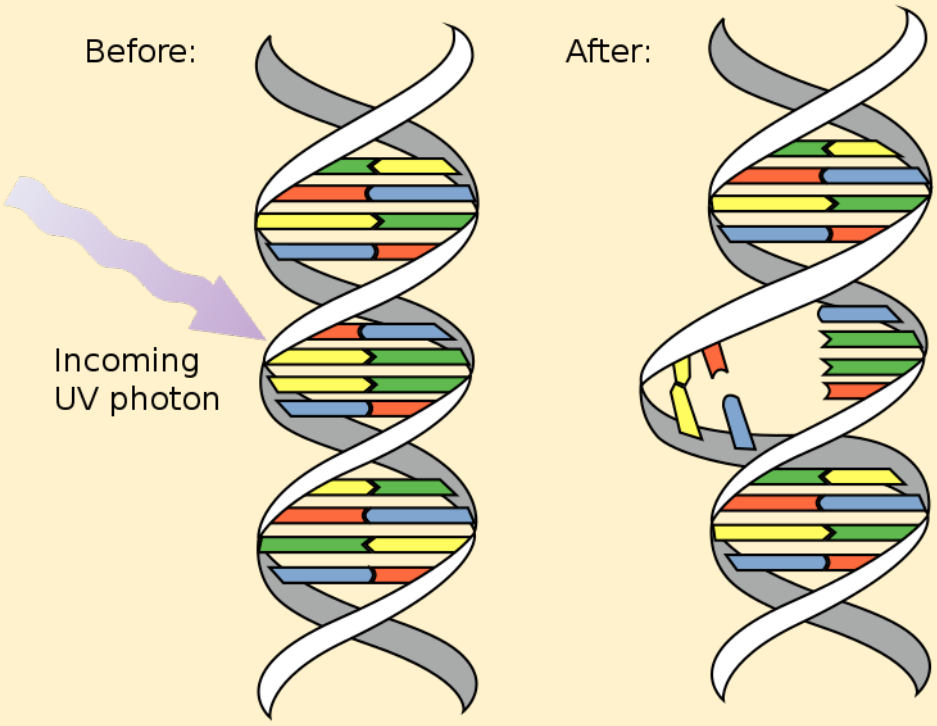
Artistic depiction of the **Stardust spacecraft**, a NASA mission launched in 1999 with the primary goal of collecting dust particles from the coma of **comet Wild 2** and interstellar dust.

## Kuiper Belt



Gerard Kuiper

Named in honour of **Gerard Kuiper**, one of the early proponents of its existence, is a region of the solar system beyond the orbit of Neptune, believed to house a plethora of comets, asteroids, and other small celestial bodies primarily composed of ice.




**Ultraviolet (UV) photons** have the ability to change the DNA of living organisms. When UV radiation interacts with **DNA** molecules, it can lead to various types of damage, including the formation of pyrimidine dimers and other **DNA** lesions. These changes can alter the genetic information stored in the **DNA**, potentially leading to mutations and affecting the proper functioning of cells. The damage caused by **UV photons** to the **DNA** can have a wide range of consequences, from cell death and genetic disorders to an increased risk of developing various health conditions, including skin cancer.



An artist's depiction showcases the extrasolar planet **OGLE-2005-BLG-390Lb** in orbit around its star, located approximately 20,000 light-years away from Earth. The discovery of this distant planet was made possible through the remarkable method of **gravitational microlensing**.

## Space trade

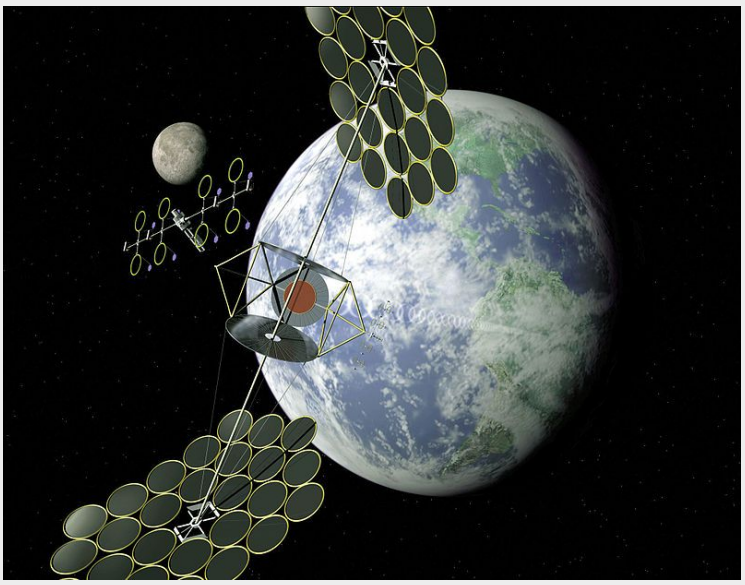
Economic activities and commerce related to space exploration, utilization, and technology.



**Commercial spaceport conception by NASA**. The **Spaceport Vision** is still in the early stages of development, but it has the potential to revolutionize the way that we launch and recover spacecraft.

## Space-based solar power

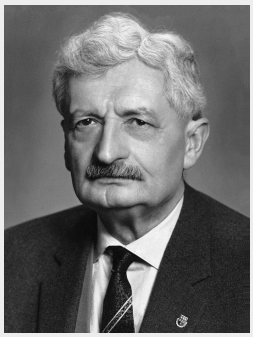
The concept of collecting solar power in outer space using **solar power satellites** (SPS) and transmitting it to Earth. The basic idea behind **SPS** involves placing large **solar panels** in space, where they can receive uninterrupted sunlight without atmospheric interference, and converting the captured solar energy into electrical power. This power is then transmitted back to Earth using microwaves or other wireless energy transfer technologies, where it can be utilized for various purposes, including providing a stable and sustainable source of electricity to meet the energy demands of homes, businesses, industries, and communities.

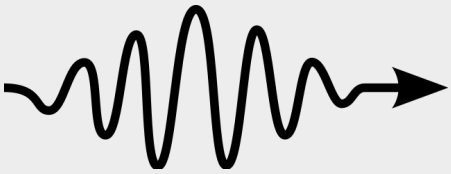


An artistic representation showcases a **solar power satellite** positioned in space, designed to efficiently harness solar energy and transmit it back to Earth. This conceptual illustration captures the essence of this advanced technology, poised to unlock the potential of space-based solar power and contribute to a sustainable energy future on our planet.

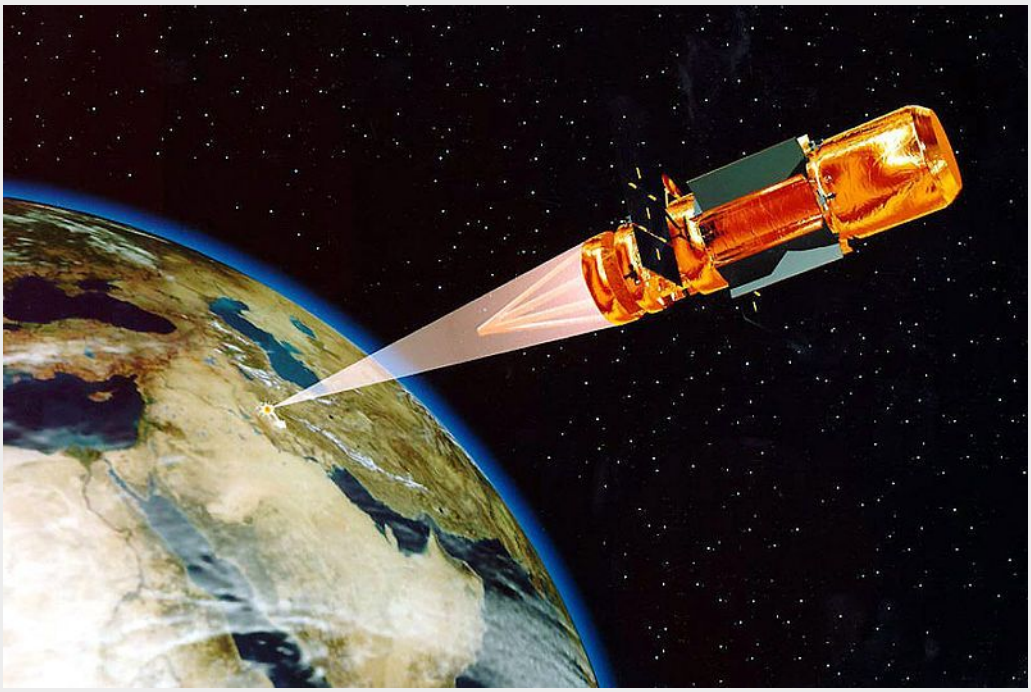
## Space mirrors

Satellites designed to manipulate the amount of solar radiation reaching the Earth's surface as a means of climate engineering. The concept of using space mirrors was initially proposed by





physicist **Hermann Oberth** in 1923 and further developed by scientists in the 1980s. The primary purpose of space mirrors is to control the solar energy received at specific points on Earth. They can be used to either increase or decrease the amount of solar radiation reaching a particular location for various applications including climate change mitigation.



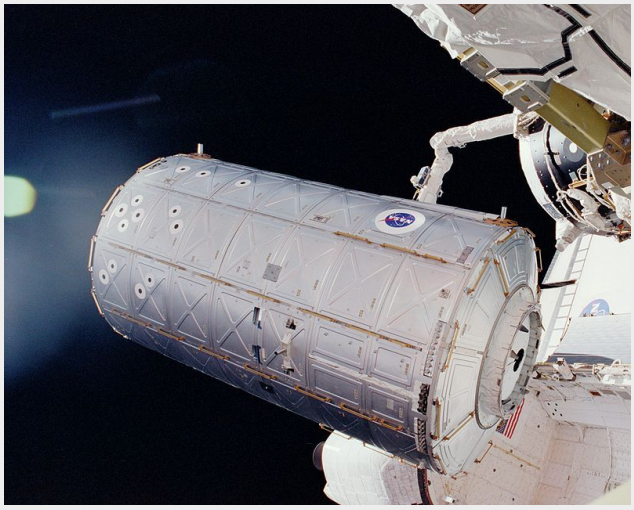
A **United States Space Command** conception of a **satellite-based directed-energy weapon** that could be used to precisely strike targets on Earth. The weapon would use a powerful beam of energy to heat or vaporize its target, and could be used to disable or destroy enemy satellites, aircraft, or even ground-based targets.

## Health threat from cosmic rays

The risks that astronauts face during interplanetary missions or any missions that traverse the **Van Allen Belts** or extend beyond **Earth's magnetosphere**.

## Space medicine

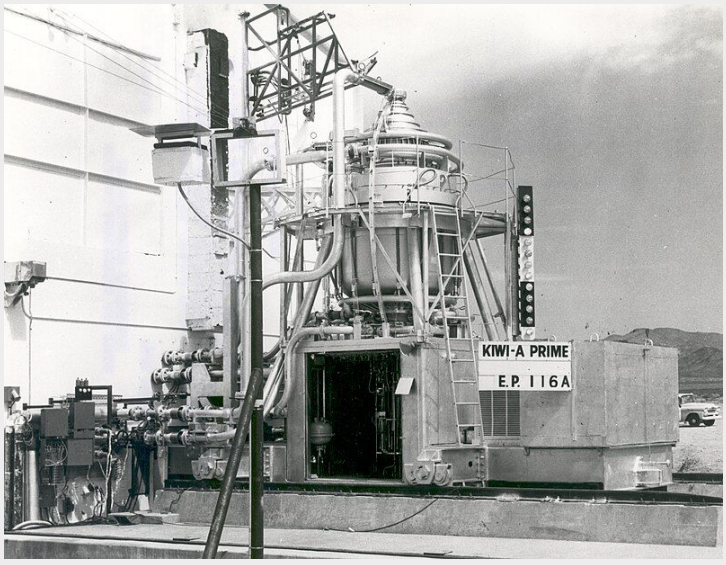
A distinct and specialized field within aerospace medicine that is dedicated to the medical care and well-being of astronauts and individuals participating in spaceflight missions. This area of study addresses the unique health challenges that arise during space travel, including the effects of microgravity, radiation exposure, isolation, and other factors associated with extended stays in space.



The **Destiny module**, alternatively referred to as the **U.S. Lab**, serves as the main operational facility for conducting U.S. research experiments and payloads on the **International Space Station** (ISS).

## Nuclear thermal rocket Engine

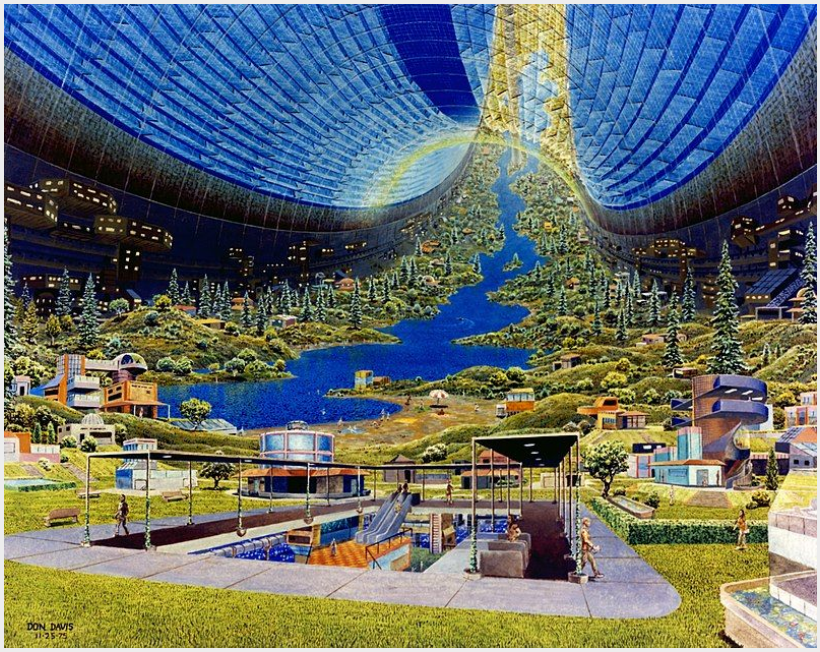
A type of rocket engine that utilizes a nuclear reactor to produce thrust.




**The KIWI** – a major success in the development of nuclear thermal rocket engines. It was the first such engine to be built and tested, and it demonstrated that hydrogen could be heated in a nuclear reactor to the temperatures required for **space propulsion**. The engine was also able to be controlled, which was another important milestone.




**Launch of a Proton rocket**, an expendable launch vehicle developed by Russia and widely utilized for deploying satellites and various payloads into space.




An artistic conception of the **Stanford Torus**, a proposed **NASA** design for a space habitat with the capacity to accommodate 10,000 to 140,000 permanent residents, has the potential to sustain human habitation in outer space.

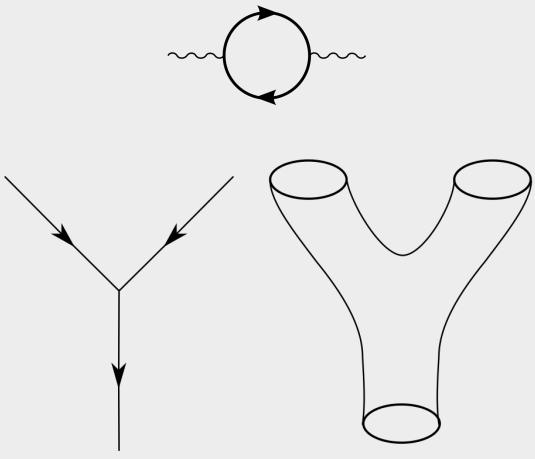
**String theory** is a theoretical framework for understanding the fundamental structure of matter and energy in the universe. Despite its popularity and its potential for explaining many phenomena, there are several problems and challenges associated with string theory that have yet to be fully resolved.



- ✓ **Lack of experimental evidence:** One of the biggest problems with string theory is that it is currently not possible to test its predictions experimentally. This makes it difficult to confirm or refute the theory.
- ✓ **Uniqueness:** It is unclear which of the numerous string theory interpretations is the most accurate. Many physicists consider this lack of uniqueness to be a weakness.
- ✓ **Complexity and Computational Challenges:** String theory is a very complex theory, and it is difficult to solve and compute the equations. This is due to the fact that string theory involves advanced mathematical concepts such as higher-dimensional geometry and abstract algebra. The complexity of string theory has a number of implications. First, it makes it difficult to understand the theory even for physicists who are familiar with quantum mechanics and general relativity. Second, it makes it difficult to test the theory experimentally. Third, it makes it difficult to apply the theory to practical problems.
- ✓ **Supersymmetry:** String theory requires the existence of supersymmetry, which states that for every known particle there is a corresponding supersymmetric partner particle. Supersymmetry has yet to be observed experimentally, and it is not clear if it exists.
- ✓ **Extra dimensions:** String theory requires the existence of extra dimensions beyond the three dimensions of space and one dimension of time that we observe. The existence of these extra dimensions is a major departure from our current understanding of the universe and has not been confirmed experimentally.

Despite these problems, many physicists believe that **string theory** has the potential to be a fundamental theory of everything, and work is ongoing to try to resolve these issues and make predictions that can be tested experimentally.





**Meteors**, also known as **shooting stars**, are small rocks or bits of debris that enter the Earth's atmosphere from space and burn up due to friction with the air. This creates a bright streak of light that is visible from the ground. **Meteors** are the result of collisions between the Earth and small bits of cosmic debris, such as asteroids or comets. When this debris enters the Earth's atmosphere, it is subjected to intense friction and heat, which causes it to vaporize and create a bright streak of light. There are several types of meteor events that can be observed, including sporadic meteors, which are random **meteor sightings** that occur throughout the year; meteor showers, which are periodic events where many meteors can be seen in a short period of time; and meteor outbursts, which are brief, intense meteor events that can produce hundreds or even thousands of meteors in a short period of time.





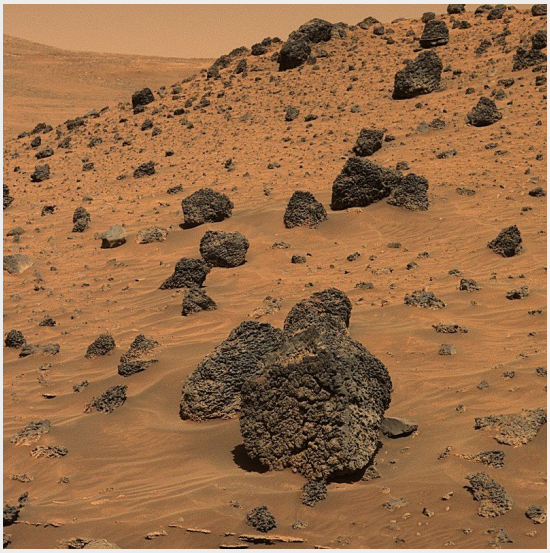
**Meteor observations** have been used for centuries to study the nature of the universe and the structure of the solar system. Today, astronomers use meteor observations to study the properties of comets and asteroids, as well as to learn about the early history of the solar system and the formation of the planets. **Meteors** can be a spectacular sight, and many people enjoy observing meteor showers and other meteor events. If you're interested in observing meteors, the best time to do so is on a clear, dark night, away from city lights. You can also find information about upcoming meteor showers **online** or in **astronomy magazines**



**Marília Meteorite**, a chondrite H4, which fell in Marília, Brazil (1971).

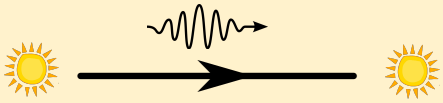
✓ **Meteor air burst** →

A type of air burst in which a meteor explodes after entering a planetary body's atmosphere.



Martian sand and boulders photographed by NASA's Mars Exploration Rover Spirit (April 13, 2006).

**Classical mechanics** is a physical theory that describes the motion of objects under the influence of forces. It was developed by **Sir Isaac Newton** in the 17th century and it gave birth to principles that remain vital today. These principles find applications in numerous fields, including calculating spacecraft trajectories and designing rockets for their launch, understanding planetary and lunar motion, as well as explaining the behaviour of everyday objects like the falling of a ball or the movement of a car on the road.



**The key concepts of classical mechanics:**

- **Mass:** The amount of matter in an object.
- **Force:** A push or pull that acts on an object.
- **Momentum:** The product of mass and velocity.
- **Energy:** The ability to do work.
- **Work:** The transfer of energy from one object to another.

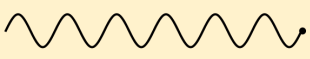


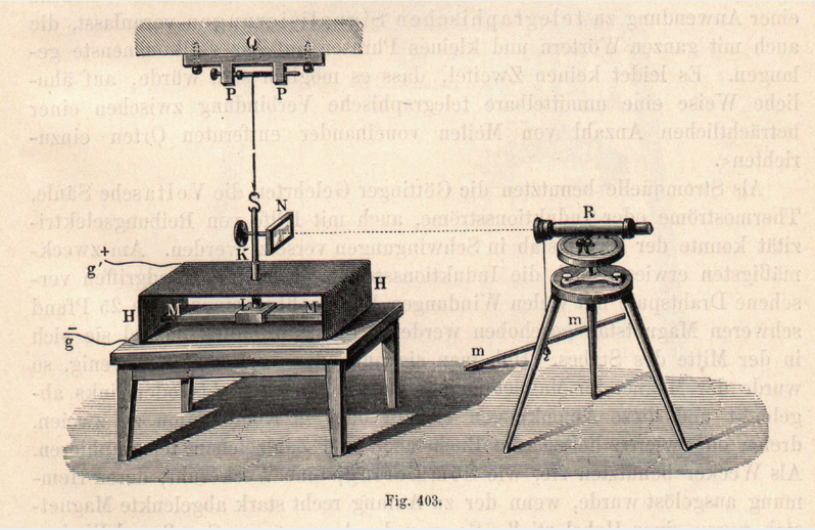
Although **classical mechanics** is a fundamental theory that has had a profound impact on our understanding of the physical world, it is not without its limitations and challenges. Let's explore some of the most notable ones.

- ✓ **It does not work at very high speeds.** When objects move at speeds close to the speed of light, classical mechanics breaks down and we need to use relativistic mechanics.
- ✓ **It does not work at very small scales.** When dealing with objects at a very small scale, such as atoms and subatomic particles, classical mechanics breaks down and we need to use quantum mechanics to understand the behaviour of particles at the subatomic level.
- ✓ **It assumes that physical quantities such as position, velocity, and momentum can be known with complete precision.** However, in the quantum world, these quantities are inherently uncertain, and the principles of quantum mechanics acknowledge and accommodate this uncertainty.

- ✓ **It cannot explain the wave-like nature of matter.** Classical mechanics treats matter as particles with well-defined positions and velocities, but quantum mechanics shows that matter can also behave like waves.
- ✓ **It cannot explain the photoelectric effect.** The photoelectric effect is the phenomenon where light can knock electrons out of a metal. Classical mechanics predicts that the energy of electromagnetic waves is continuous and depends on the intensity of light. This means that a dim light would take some time to eject electrons from a metal surface, because the electrons would need to gather enough energy from the light waves before they could escape. However, this is not what is observed in the photoelectric effect. Instead, it is found that even a dim light can eject electrons immediately, as long as the light has a frequency that is above a certain threshold value.
- ✓ **It cannot explain the stability of atoms.** In classical mechanics, electrons orbiting the hydrogen nucleus would be constantly changing direction and accelerating, leading one to expect that they should emit electromagnetic radiation, losing energy over time, and ultimately collapse into the nucleus in only about 0.000000000001 second. However, this classical understanding does not hold true in reality.
- ✓ **It cannot explain blackbody radiation.** Classical mechanics predicts that a blackbody can emit electromagnetic radiation of any wavelength. However, this is not correct. The wavelength range of the radiation emitted by a blackbody is determined by the frequency of the electromagnetic radiation, and it is emitted as discrete packets of energy called photons. In classical mechanics, electromagnetic radiation is treated as a continuous wave. This means that the radiation can have any wavelength, and the intensity of the radiation will be the same at all wavelengths. However, this is not what is observed in reality. The spectrum of blackbody radiation is peaked at a certain wavelength, and the intensity of the radiation decreases as the wavelength gets shorter or longer.

**Classical mechanics** continues to be a valuable and significant theory, finding widespread use in various areas of physics and engineering. However, in specific scenarios involving extremely small or fast-moving objects, or when gravitational effects are prominent, classical mechanics needs to be supplemented by more sophisticated theories like **quantum mechanics and general relativity**. These advanced theories provide a more comprehensive understanding of phenomena at the atomic, subatomic, and cosmic scales, where classical mechanics alone falls short.









✓ **A magnetometer used by Carl Friedrich Gauss.**

According to **Bohr's model of the hydrogen atom**, electrons possess more energy when they are in larger orbits compared to smaller ones. When an electron moves from a larger orbit to a smaller one, it releases the excess energy. As per the **law of conservation of energy**, this energy cannot simply disappear; instead, Bohr proposed that it is carried away by a photon. The energy carried by the photon is precisely equal to the difference between the electron's energy in the larger and smaller orbits. Mathematically, it can be expressed as:

Photon energy = (Electron energy in larger orbit) – (Electron energy in smaller orbit)

Conversely, if a photon with precisely the same energy as the energy difference between two orbital states strikes an atom, the atom can absorb the photon's energy. In this scenario, the atom's electron utilizes the photon's energy to make a **"quantum jump"** from the smaller orbit to the larger one. This concept of quantized energy levels and the exchange of energy through photons helped explain the stability of atoms and provided a foundation for the development of quantum mechanics.

Energy of a vibrating electron = Planck's constant × frequency of vibration

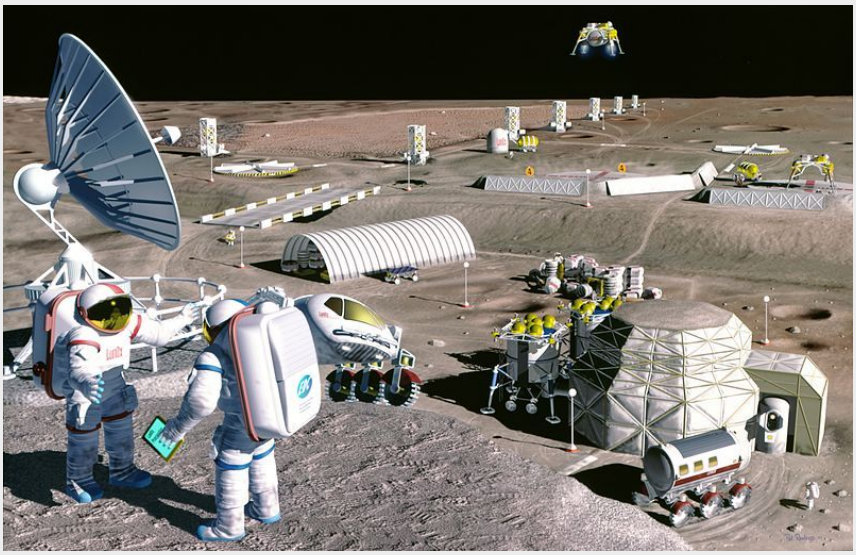
$$E = h\upsilon$$

To vibrate and emit light, the vibrating electron must possess a minimum energy of $h\upsilon$. If the electron does not have at least this minimum amount of energy, $h\upsilon$, it will not vibrate at all, and consequently, it will not be able to emit any light.

## ✓ Active SETI

## (Active Search for Extra-Terrestrial Intelligence)

The deliberate attempt to send messages from Earth to potential **extraterrestrial civilizations** in the hope of initiating communication with intelligent beings beyond our planet. These messages are typically transmitted in the form of **radio signals** due to radio waves' ability to travel through space without significant degradation.

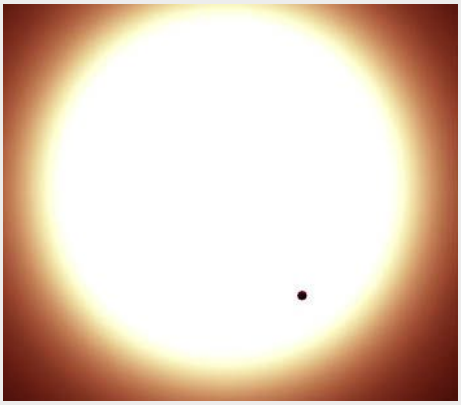


An artistic depiction of an envisioned lunar mining facility

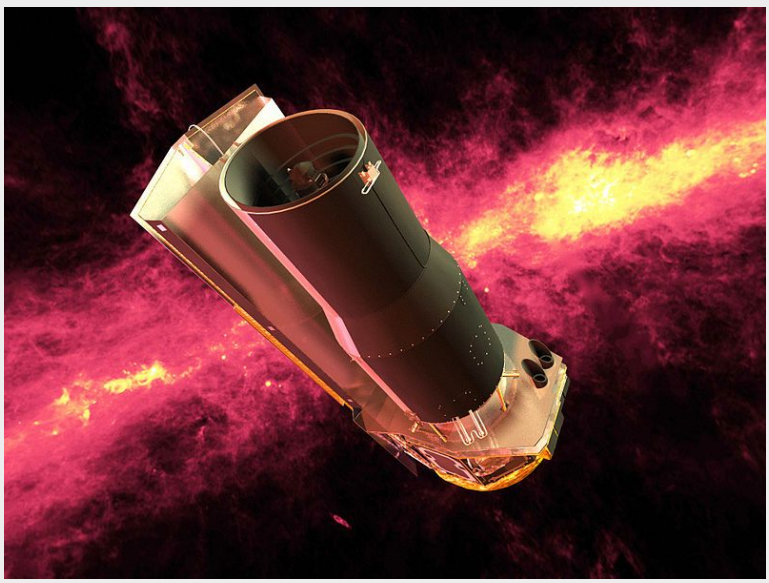
## Across the Universe



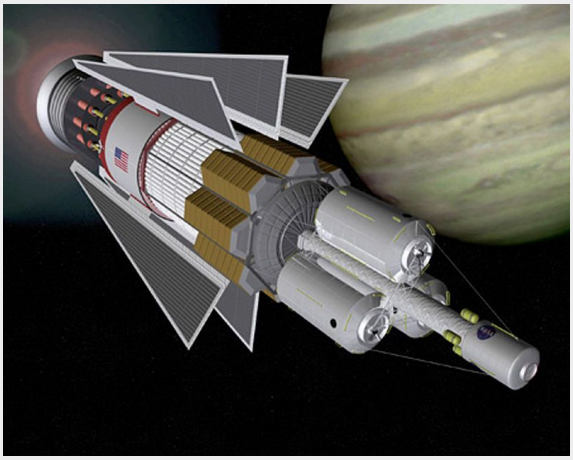
An interstellar radio message (IRM) transmitted by **NASA** on February 4, 2008, at 00:00 UTC. This message consists of the song **"Across the Universe"** by the Beatles and was directed towards the star Polaris as a symbolic gesture to reach out to the cosmos.



This image depicts an artist's conception of the exoplanet **CoRoT-7b** during a transit event. CoRoT-7b is shown passing in front of its host star, a yellow dwarf star known as **CoRoT-7**.



Artistic depiction of the **Spitzer Space Telescope**, an infrared space telescope launched on August 25, 2003, and it operated for 16 years, until January 30, 2020.



**Pulsed fission propulsion**, a type of nuclear propulsion that uses the energy released from nuclear fission to produce thrust. It is a more efficient and powerful form of propulsion than traditional chemical rockets, and it could potentially be used to travel to distant stars. **Pulsed fission propulsion** has a number of advantages over traditional chemical rockets. It is more efficient, meaning that it can produce more thrust for a given amount of propellant. It is also more powerful, meaning that it can propel a spacecraft to higher speeds. However, pulsed fission propulsion also has some disadvantages. It is more complex and expensive than traditional chemical rockets. It also produces a significant amount of radiation, which could be a hazard to the crew of the spacecraft.

## Wow! Signal

A strong, narrowband radio signal detected by Ohio State University's Big Ear radio telescope on August 15, 1977. The signal came from the direction of the constellation **Sagittarius** and had characteristics that suggested it was from an extraterrestrial civilization.

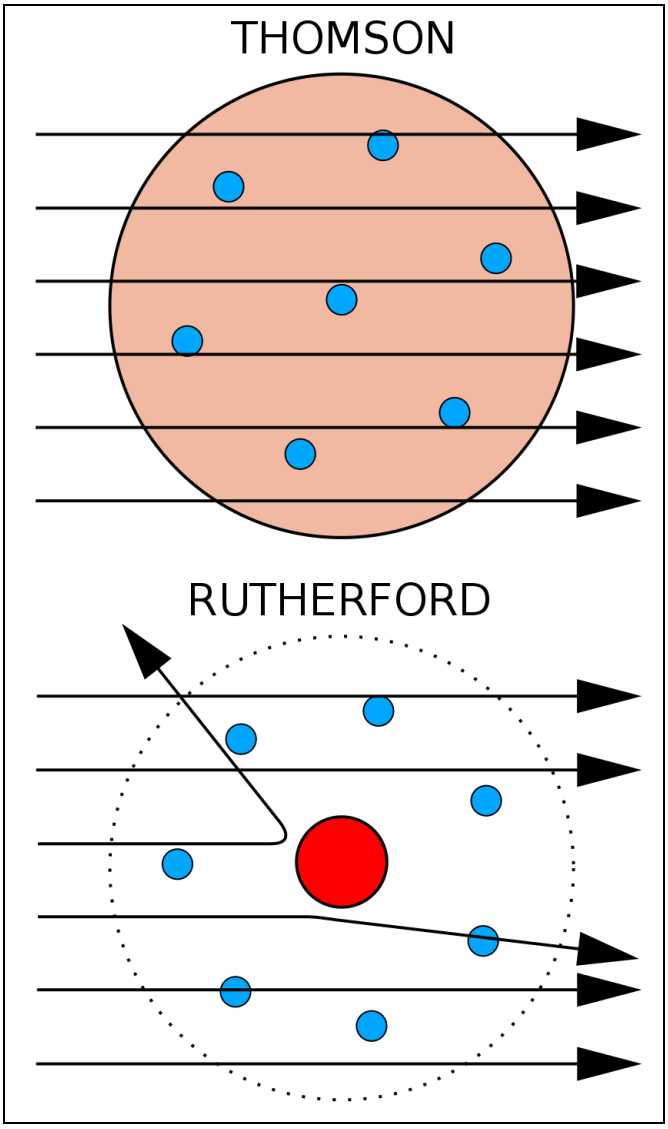
## ✓ Fast radio bursts (FRBs)

Enigmatic and puzzling astronomical occurrences characterized by short, powerful bursts of radio waves. These bursts typically last for only a fraction of a millisecond to a few seconds, and they originate from distant regions in space. Despite extensive research and observation, the precise source and cause of **FRBs** remain elusive, leaving scientists intrigued and seeking to unravel the mystery behind these fascinating cosmic events.

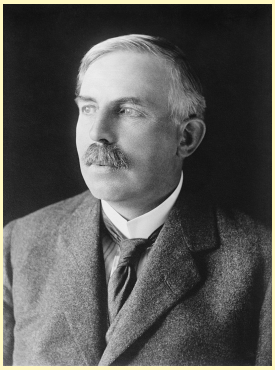




**Joseph-Louis Lagrange** (1736−1813) was an **Italian-French mathematician and astronomer** who made significant contributions to several fields of mathematics, including algebra, number theory, and calculus. He is widely regarded as one of the greatest mathematicians of the 18th century. **Lagrange** was born in Turin, Italy, but he spent most of his career in France. He held positions at the **Royal Military School** in Turin, the Berlin Academy, and the **Ecole Polytechnique in Paris**, among others. He was also a member of several scientific societies, including the **Royal Society of London and the Academy of Sciences in Paris**. Among **Lagrange's most important contributions** to mathematics are his work on the calculus of variations, which laid the groundwork for modern optimization theory, and his formulation of the principle of least action, which has had a profound impact on physics. He also made significant contributions to the **theory of differential equations**, **number theory**, and **algebraic geometry**. **Lagrange** was known for his elegance and clarity in mathematical writing, and his work had a significant influence on the development of mathematics in the 19th century. He died in Paris in 1813.

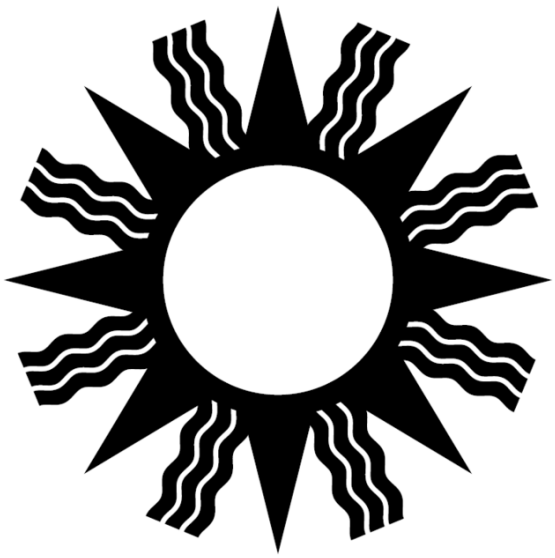



**Ernest Rutherford's experiment**, also known as the **gold foil experiment**, was a landmark experiment in the field of nuclear physics conducted in 1911. The experiment was designed to investigate the structure of the atom and to test the validity of the **Thomson model of the atom**. The experiment involved firing a beam of alpha particles (positively charged particles) at a thin sheet of gold foil. The **alpha particles** were emitted by a sample of radioactive material and were directed at the gold foil by a device called a collimator. The gold foil was placed on a detector screen coated with a material that would produce a flash of light when struck by an alpha particle.



According to the **Thomson model of the atom**, the alpha particles should pass straight through the gold foil with only slight deflections due to the evenly distributed positive charge of the atom. However, **Rutherford** observed that a small number of alpha particles were deflected at large angles, and some even bounced straight back towards the source. This unexpected result led **Rutherford** to conclude that the positive charge of the atom is concentrated in a tiny, central region called the nucleus, while the rest of the atom is mostly empty space. The deflection of the alpha particles was attributed to the repulsion between the positively charged alpha particles and the positively charged nucleus of the gold atoms. **Rutherford's experiment** was a significant breakthrough in the field of atomic physics and led to the development of the modern understanding of the structure of the atom.

**Helioseismology** is a branch of astronomy that studies the internal structure and dynamics of the Sun using the science of seismology. Just as earthquakes produce seismic waves that travel through the Earth, the Sun also produces waves, known as **solar waves** or **helioseismic waves,** which travel through its interior.

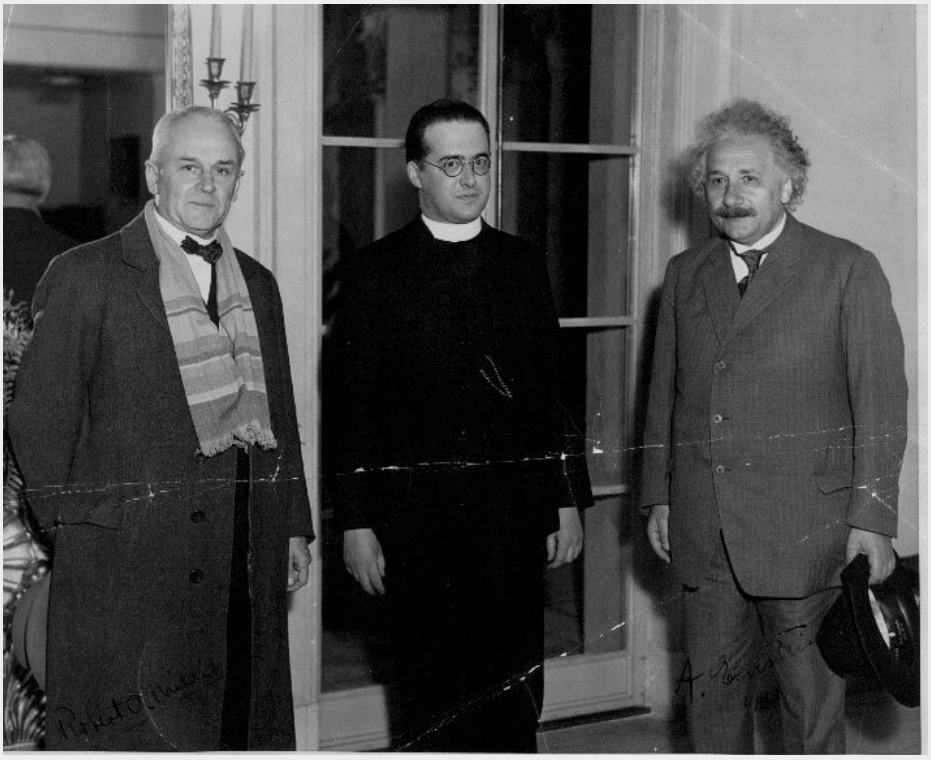


By studying the behavior of these solar waves, scientists can probe the Sun's interior and learn about its structure and dynamics. This information is critical for understanding the processes that drive the Sun's energy output, such as **nuclear fusion**, and the mechanisms that cause the Sun's magnetic activity, such as sunspots and solar flares. **Helioseismology** has been extremely successful in advancing our understanding of the Sun. For example, it has allowed scientists to determine the internal rotation rate of the Sun, the size and location of its **convective zone**, and the properties of its magnetic field. It has also provided important constraints on models of solar evolution and on theories of the solar interior. The study of **Helioseismology** is typically done using data from space-based observatories, such as the **Solar and Heliospheric Observatory** (SOHO) or the **Solar Dynamics Observatory** (SDO), which provide detailed images and observations of the Sun's surface and atmosphere. By analyzing these observations, scientists can infer the properties of the Sun's interior and study its behavior over time.

# Most important milestones in the history of cosmology

- ✓ **Ancient Cosmologies:** Many ancient civilizations developed cosmological models to explain the universe. These models ranged from the **flat earth cosmology** of the **Ancient Greeks** to the elaborate cosmologies of the **Mayans** and the **Hindus**. These ancient cosmological models were attempts to understand the nature of the cosmos and our place within it, reflecting the rich diversity of human perspectives and the pursuit of knowledge in ancient times.
- ✓ **16th-18th Century:** The Scientific Revolution marked a pivotal period in our comprehension of the universe. During this era, astronomers like **Copernicus**, **Kepler**, and **Galileo** played key roles in advancing our understanding by employing observation and mathematical models. Their ground-breaking work challenged the prevailing **geocentric model**, which asserted that the Earth was the center of the universe. Through their discoveries and insights, these scientists paved the way for the eventual acceptance of the **heliocentric model**, where the Sun became recognized as the central body around which the planets, including Earth, revolve.
- ✓ **1915: Einstein's theory of General Relativity:** Albert Einstein revolutionized our understanding of space and time by introducing his theory of General Relativity. This ground-breaking theory fundamentally transformed our understanding of gravity and provided the cornerstone for modern cosmology. In essence, **General Relativity** proposes that gravity is not a force as traditionally understood, but rather the result of the curvature of spacetime caused by the presence of mass and energy. This elegant and profound concept reshaped our perception of the universe and remains one of the most significant contributions to theoretical physics.
- ✓ **1927: The Big Bang Theory:** Georges Lemaître proposed the theory of the Big Bang, which states that the universe began as a single point of infinite density and temperature, and has been expanding ever since. Subsequent to **Lemaître's proposal**, observations of **cosmic microwave background radiation** provided compelling evidence supporting the Big Bang theory. This remarkable idea has become the prevailing

explanation for the origin and evolution of the universe, significantly shaping our understanding of the cosmos.

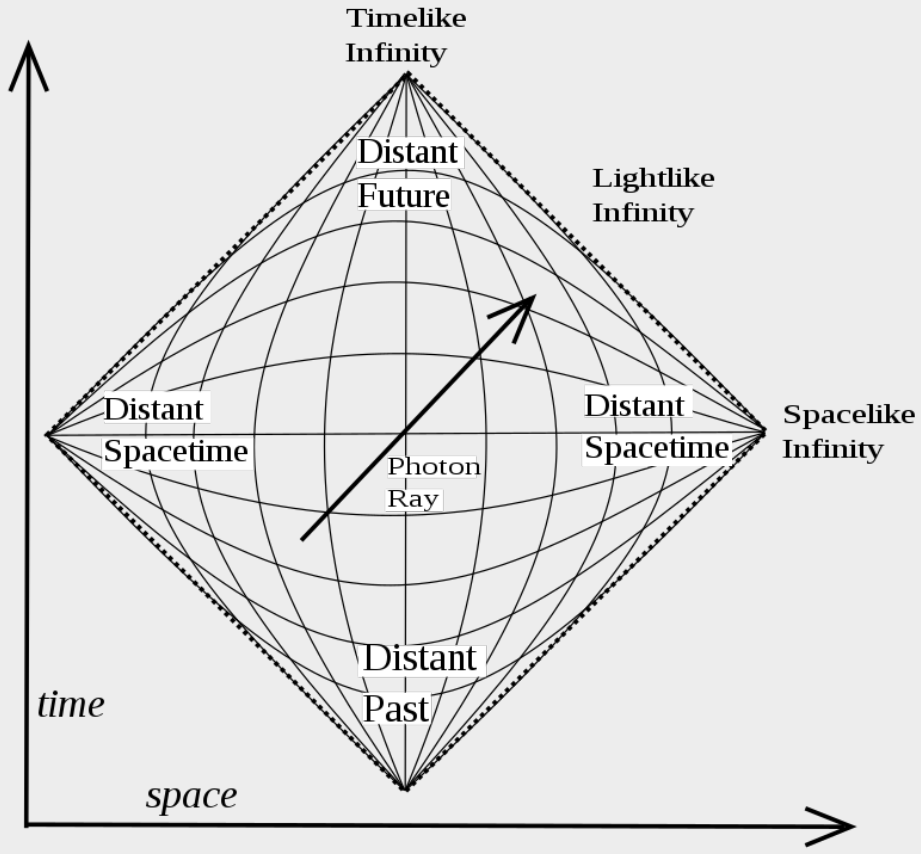


**Robert Millikan, Lemaître** and **Albert Einstein after Lemaître's lecture** at the **California Institute of Technology** in January 1933**.**

- ✓ **1948: The steady-state theory:** Hermann Bondi, Thomas Gold, and Fred Hoyle proposed the steady-state theory, which suggested that the universe has no beginning or end and that new matter is continuously created to maintain a **constant density**. The theory was later disproved by observations of the cosmic microwave background radiation.
- ✓ **1964: Discovery of cosmic microwave background radiation:** Arno Penzias and Robert Wilson discovered the **cosmic microwave background radiation**, which provided strong evidence in favour of the Big Bang theory.
- ✓ **1970s: Dark Matter:** Vera Rubin and Kent Ford made a significant discovery by identifying a mysterious substance, which they termed dark matter. This enigmatic matter cannot be directly observed, but its existence is deduced from its gravitational influence on visible matter. Their ground-breaking work shed light on this elusive

component of the universe that plays a crucial role in shaping its structure and dynamics.

- ✓ **1980s: Inflationary theory:** Alan Guth proposed the **inflationary theory**, which suggests that the universe underwent a brief period of rapid expansion just after the Big Bang, which solved some of the problems with the standard Big Bang model.
- ✓ **1998: Discovery of cosmic acceleration:** Two independent teams of astronomers discovered that the expansion of the universe is accelerating, which led to the discovery of dark energy, a mysterious force that is causing the acceleration.
- ✓ **2013: Planck satellite results:** The European Space Agency's Planck satellite provided the most detailed map of the **cosmic microwave background radiation**, which confirmed many predictions of the Big Bang theory and refined our understanding of the composition of the universe.




**The Penrose-Carter diagram of an infinite Minkowski universe**. This diagram is a visual representation used in the study of special relativity and cosmology to depict the spacetime structure of an infinite, flat, and unbounded universe described by **Minkowski spacetime**.

## Current Mysteries from Observations

# MAPPING THE DARK UNIVERSE

**Dark Matter?**

Holds Galaxies together

Triggers Galaxy formation

**Dark Energy?**

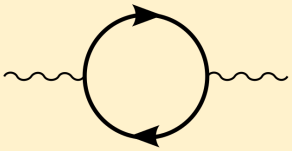
Drives Cosmic Acceleration

How Can We Make It In The Laboratory?

Are There Undiscovered Principles of Nature: New Symmetries, New Physical Laws?

The relationship between quantum mechanics and general relativity?

**The fate of the universe?**

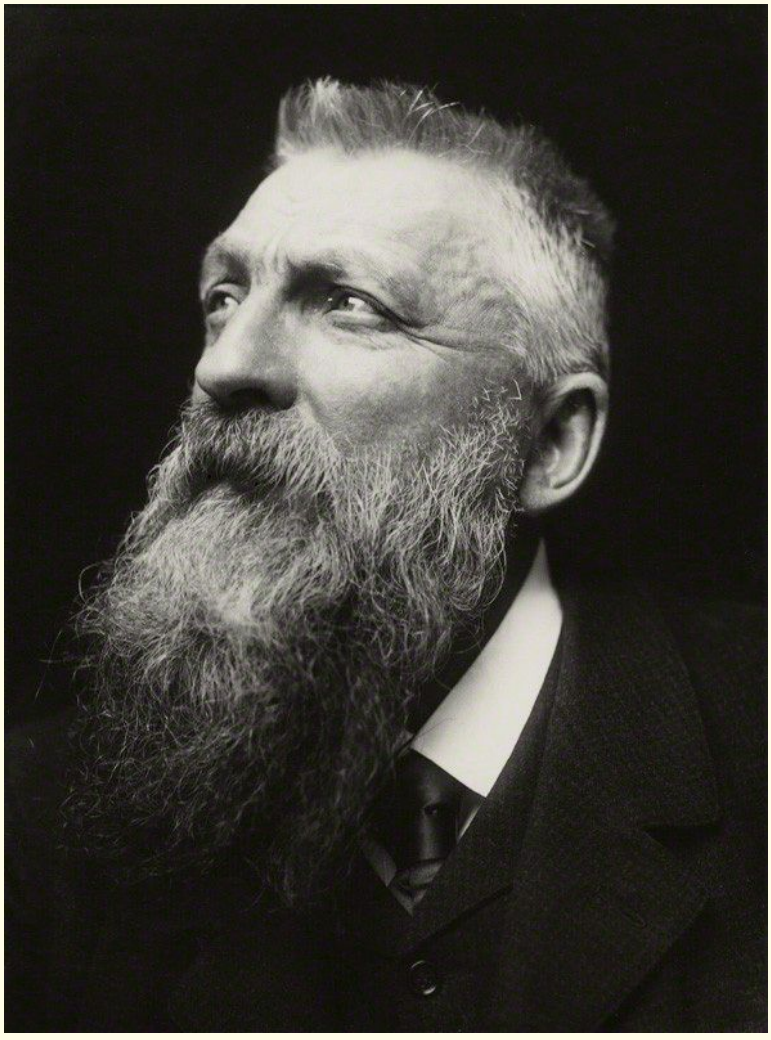


## UNKNOWN FORCES?

Are Elementary particles just manifestations of a more fundamental layer of nature described by one Dimensional string $10^{-35}$ m in length?

With new cosmic surveys, we are aiming to address these mysteries and learn more about the evolution of the cosmos.

"There are unknown forces in nature; when we give ourselves wholly to her, without reserve, she lends them to us; she shows us these forms, which our watching eyes do not see, which our intelligence does not understand or suspect."



**–Auguste Rodin**

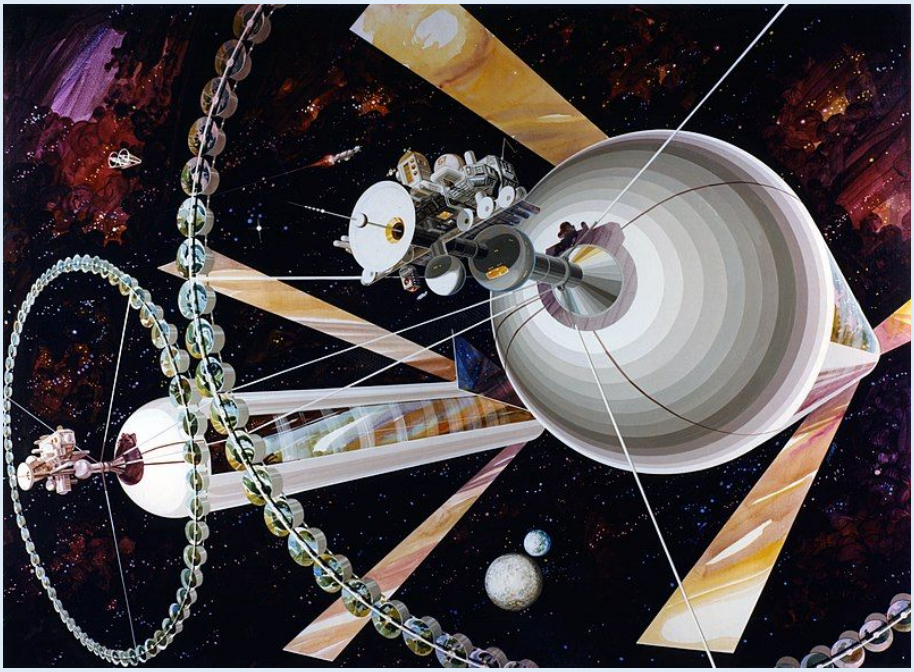
(The founder of modern sculpture)



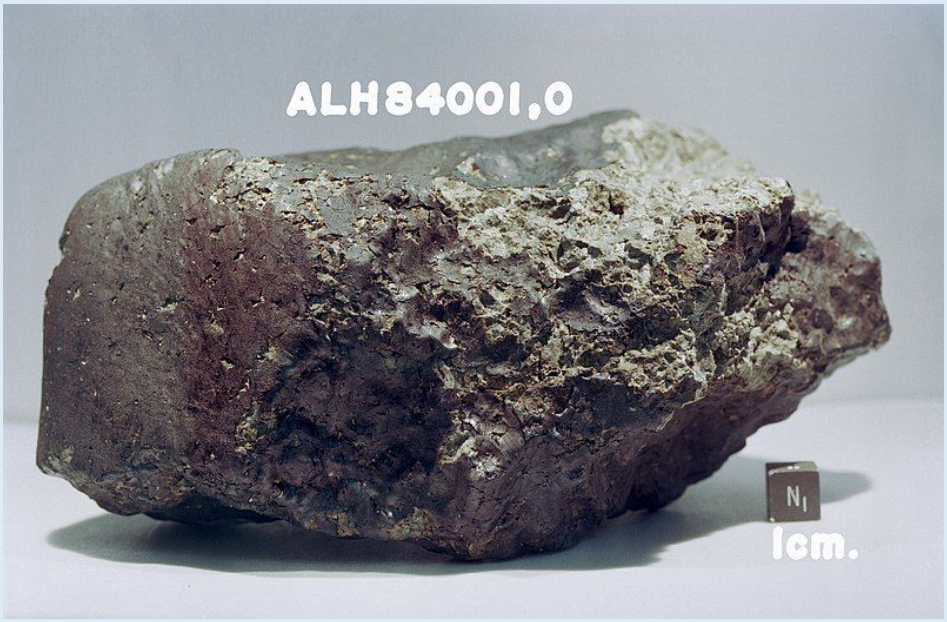


✓ **Viking 1 orbiter**

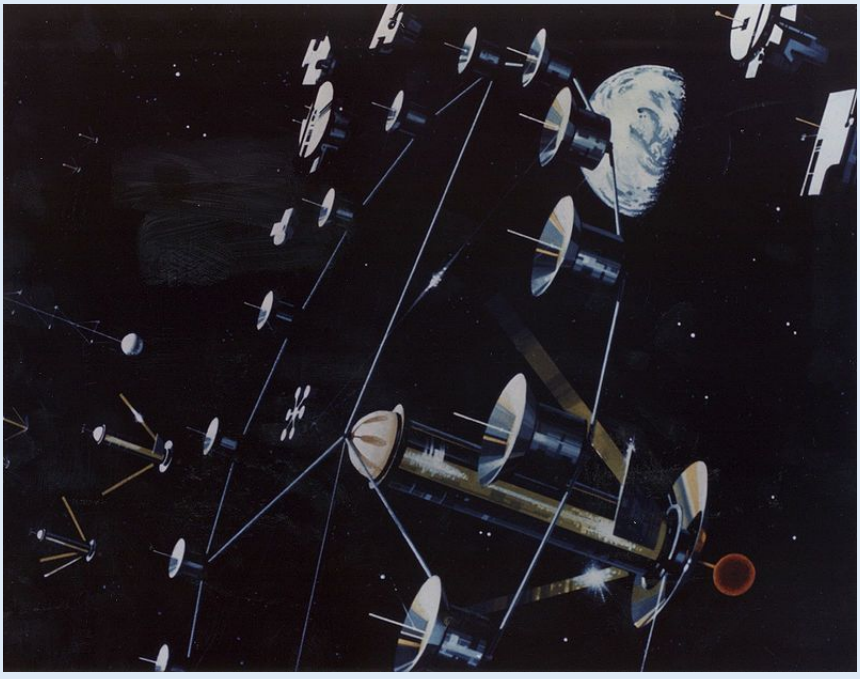
In this image captured by the **Viking 1 orbiter**, we can observe the thin atmosphere of Mars. The photograph showcases the mountains located in the southern region of the Argyre Basin, with the Galle crater positioned left of center.



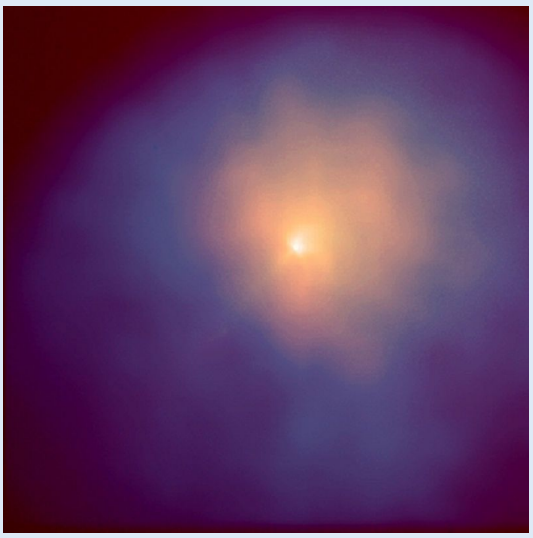
An artistic representation showcasing a pair of **O'Neill cylinders**. These space settlement structures, proposed by **Gerard K. O'Neill**, are designed to sustain human life and activities in space, offering a vision of potential future habitats beyond Earth.




**Mars meteorite ALH84001**, a significant and famous rock that was found in Antarctica in 1984. It belongs to the SNC (Shergottite-Nakhla-Chassignite) group, which are meteorites believed to have originated from Mars.



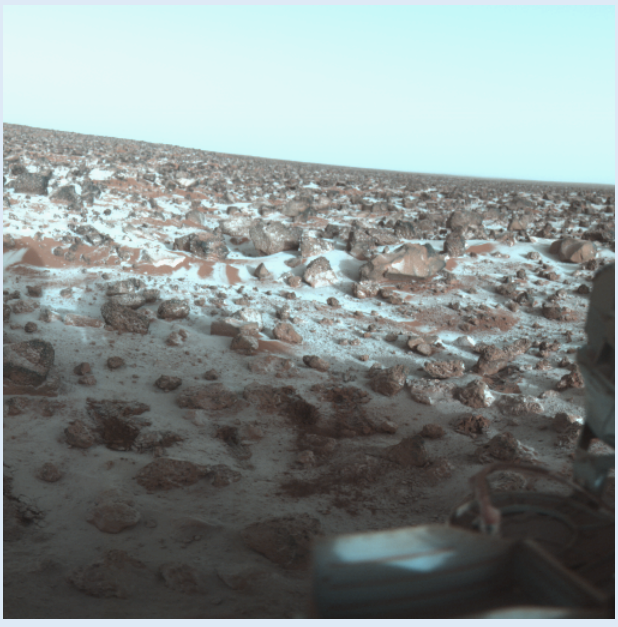
This is a NASA concept image depicting multiple habitat cylinders arranged in a configuration facing the Sun. The illustration showcases a potential design for space settlements that utilize sunlight as a primary energy source for sustaining human habitats in space.



**Comet Hyakutake** captured by the Hubble Space Telescope on 4 April 1996, with an infrared filter.

## Biosphere 2

An Earth system science research facility situated in Oracle, Arizona, USA. Its core purpose is to act as a hub for research, education, outreach, and continuous learning, with a central focus on Earth, its ecosystems, and its position in the cosmos.



A thin coating of water ice covering the Martian plain **Utopia Planitia** (taken by the Viking 2 lander)

- Planck's constant → the scale of the quantum world.
- Speed of light → encodes the Einstein's relativity principle.
- Newton's constant → quantifies the strength of the force of gravity.

"String theory is different to religion because of its utility in mathematics and quantum field theory, and because it may someday evolve into a testable theory (aka science)."



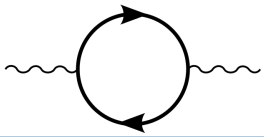
**−Sheldon Glashow**

"Early claims that string theory would provide a "theory of everything" now seem hollow indeed. But we'll soon be awash in LHC data, and we haven't yet channelled the flood of recent advances in cosmology into fundamental physics. With luck, string theory might become a theory of something."



**−Frank Wilczek**

"It is too early to tell how the string landscape is populated. Anthropic arguments ought to work unless it is very selectively populated, but we just don't know whether that is the case. It seems to me that at this point, all avenues should be tried."



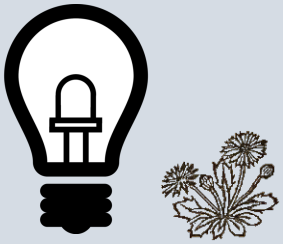
**−Steven Weinberg**

**Units make sense:**

$$\text{Energy density} = \frac{\text{Energy}}{\text{volume}} = \frac{\text{Force} \times \text{length}}{(\text{length})^3} = \frac{\text{Force}}{\text{area}} = \text{Pressure}$$

**Cherenkov radiation** refers to the electromagnetic radiation emitted when a charged particle passes through a dielectric medium at a speed greater than the phase velocity of light in that medium. The phenomenon can be described mathematically using the **Cherenkov radiation formula**:

$$\cos\theta = \frac{1}{\beta n}$$



where θ is the **Cherenkov angle** (which is the angle between the direction of the charged particle's motion and the direction of the emitted radiation), β is the velocity of the charged particle "v " divided by the speed of light "c " in vacuum (i.e., $\beta = \frac{v}{c}$ ) and n is the refractive index of the dielectric medium.

**Let's consider an example:**

Suppose we have an electron moving through water with a velocity of v = 0.9c. The refractive index of water is approximately n = 1.33. We can calculate the **Cherenkov angle** (θ) using the formula mentioned above.

First, we need to calculate $\beta = \frac{v}{c} = \frac{0.9c}{c} = 0.9$

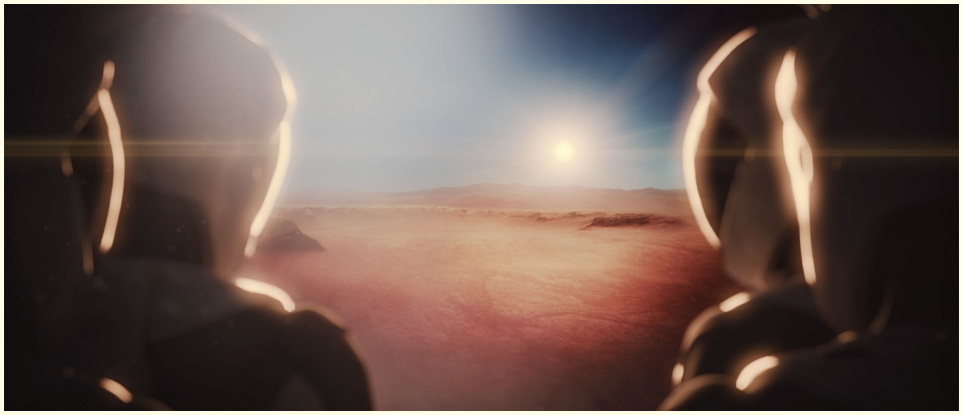
Now, we can substitute the values into the **Cherenkov radiation formula**:

$$\cos\theta = \frac{1}{0.9 \times 1.33} = 0.83542188805$$

$$\theta = \cos^{-1}(0.83542188805)$$

$$\theta \approx 33.34^{o}$$

Therefore, in this example, the **Cherenkov angle** for an electron moving at a velocity of 0.9c through water is approximately $33.34^{o}$.



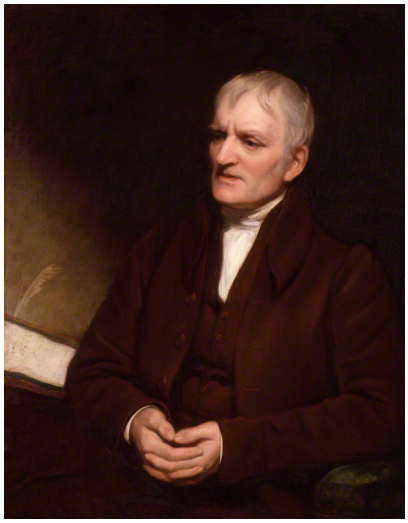
**A scene of astronauts on Mars in the 2016 IAC presentation.**

Matter, though divisible in an extreme degree, is nevertheless not infinitely divisible. That is, there must be some point beyond which we cannot go in the division of matter.…I have chosen the word "atom" to signify these ultimate particles.

— John Dalton

## John Dalton's atomic theory of matter:

- All matter is composed of atoms.
- Atoms cannot be made or destroyed.
- All atoms of the same element are identical.
- Different elements have different types of atoms.
- Chemical reactions occur when atoms are rearranged.
- Compounds are formed from atoms of the constituent elements



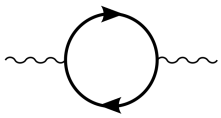



## Noether's Theorem:

For every continuous symmetry of the laws of physics, there must exist a conservation law.

For every conservation law, there must exist a continuous symmetry.

What, then, is light according to the electromagnetic theory? It consists of alternate and opposite rapidly recurring transverse magnetic disturbances, accompanied with electric displacements, the direction of the electric displacement being at the right angles to the magnetic disturbance, and both at right angles to the direction of the ray.

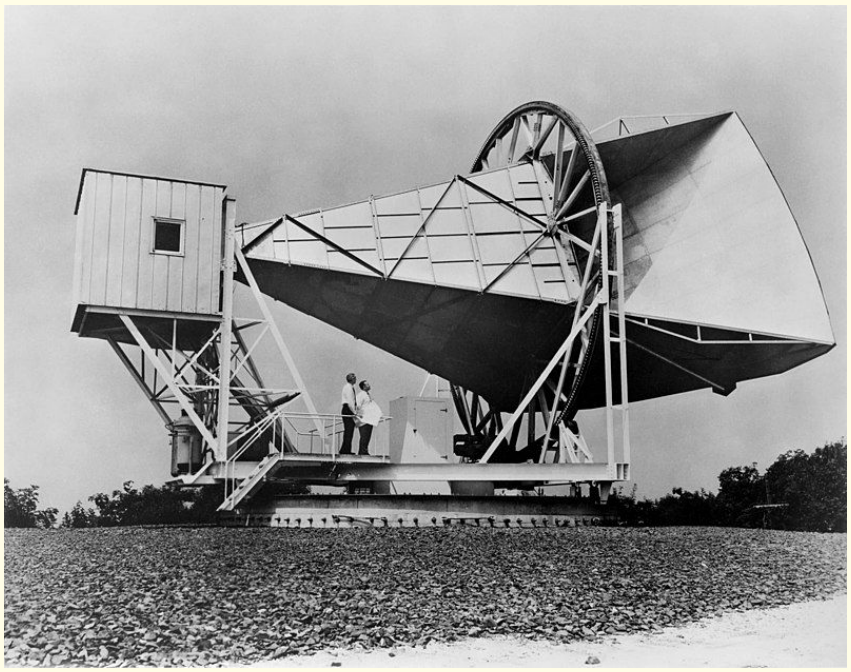


**— James Clerk Maxwell**

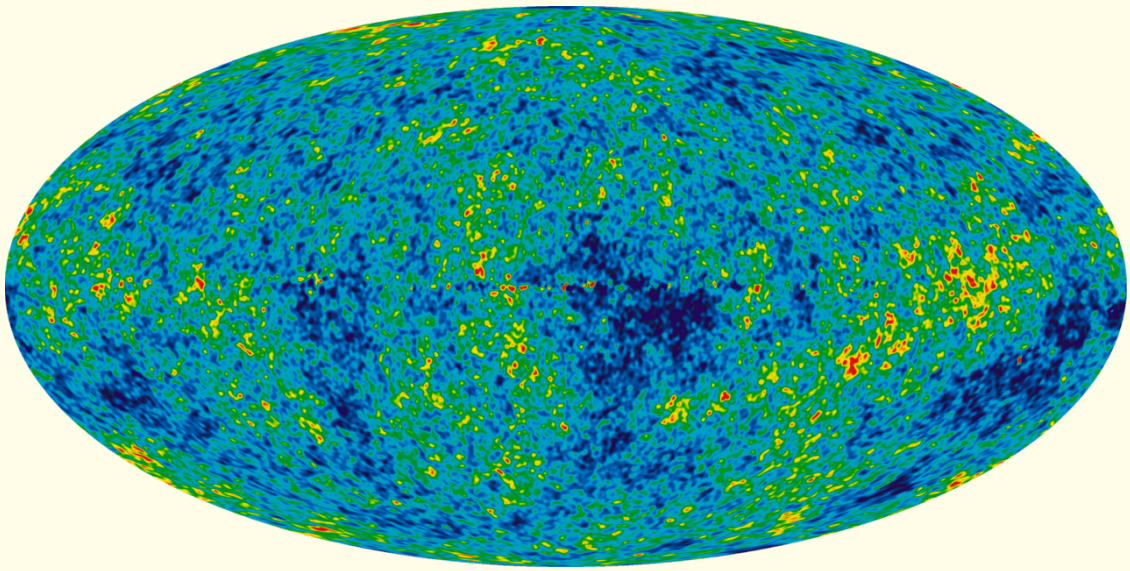
Natural science is not concerned with Nature itself, but with Nature as man describes and understands it. This does not mean that an element of subjectivity is introduced into natural science—no one claims that the processes and phenomena that take place in the world are dependent on our observations—but attention is brought to the fact that natural science stands between man and nature and that we cannot dispense with the aid of perceptual concepts or other concepts inherent in the nature of man.



**– Werner Heisenberg**



**The Holmdel Horn Antenna on which Penzias and Wilson discovered the cosmic microwave background.**



**WMAP image of the (extremely tiny) anisotropies in the cosmic background radiation**

"We must be careful, though, that we don’t confuse the issue by contaminating the planet with life from Earth. Similarly, we must be very careful not to bring back any Martian life. We would have no resistance to it, and it might wipe out life on Earth."



**— Stephen Hawking, Brief Answers to the Big Questions**

The energy acquired by an electron of charge **e** when a voltage **V** is applied to it can be calculated using the following formula:

$$E = eV$$

where E is the energy in joules, e is the charge of an electron (which is approximately $1.602 \times 10^{-19}$ coulombs), and V is the voltage in volts. **For example,** if a voltage of 10 volts is applied to an electron, the energy acquired by the electron can be calculated as:

$$E = (1.602 \times 10^{-19}\ C) \times (10\ V) = 1.602 \times 10^{-18}\ J$$

Therefore, the electron acquires energy of about $1.602 \times 10^{-18}$ joules.

## Planck Energy

The energy acquired by a particle of **Planck charge** when a **Planck voltage** is applied to it

✓ **Planck Energy = Planck charge × Planck voltage**

$$\sqrt{\frac{\hbar c^5}{G}} = \sqrt{4\pi\varepsilon_0 \hbar c} \times \text{Planck voltage}$$

$$\text{Planck voltage} = \sqrt{\frac{c^4}{G 4\pi\varepsilon_0}} \approx 1.043 \times 10^{27} V$$

✓ **Planck current** = $\frac{\text{Planck charge}}{\text{Planck time}} = \frac{\sqrt{4\pi\varepsilon_0\hbar c}}{\sqrt{\frac{\hbar G}{c^5}}}$

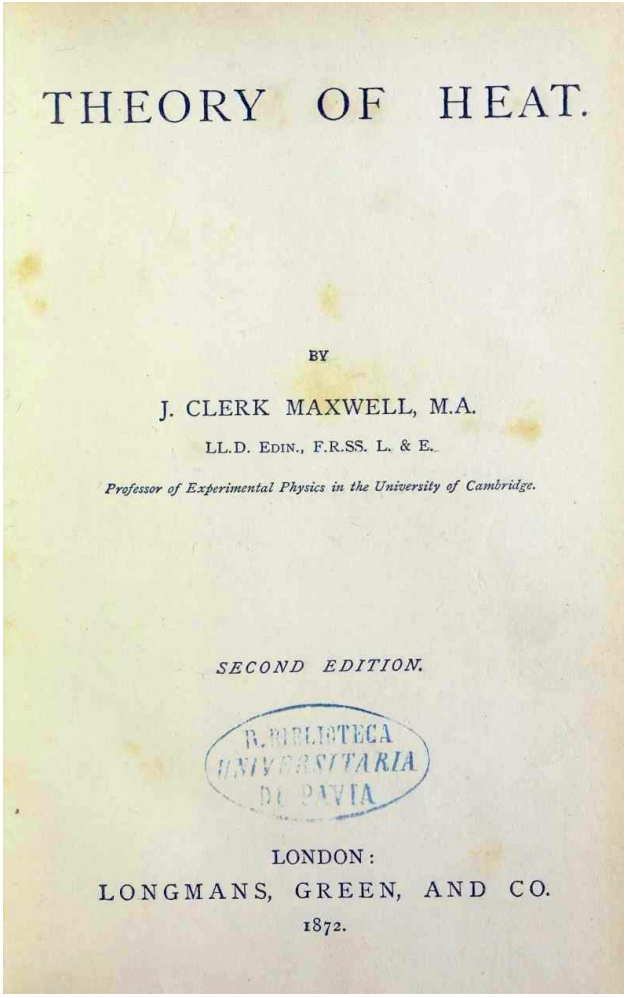
**Planck current** = $\sqrt{\frac{4\pi\varepsilon_0 c^6}{G}} \approx 3.479 \times 10^{25}\text{A}$

**Planck resistance** = $\frac{\text{Planck voltage}}{\text{Planck current}} = \frac{\sqrt{\frac{c^4}{G4\pi\varepsilon_0}}}{\sqrt{\frac{4\pi\varepsilon_0 c^6}{G}}}$

**Planck resistance** = $\frac{1}{4\pi\varepsilon_0 c}$

**Planck power** = $\frac{\text{Planck energy}}{\text{Planck time}}$ = **Planck current × Planck voltage**

**Planck power = (Planck current)$^2$ × Planck resistance**



THEORY OF HEAT.

BY

J. CLERK MAXWELL, M.A.

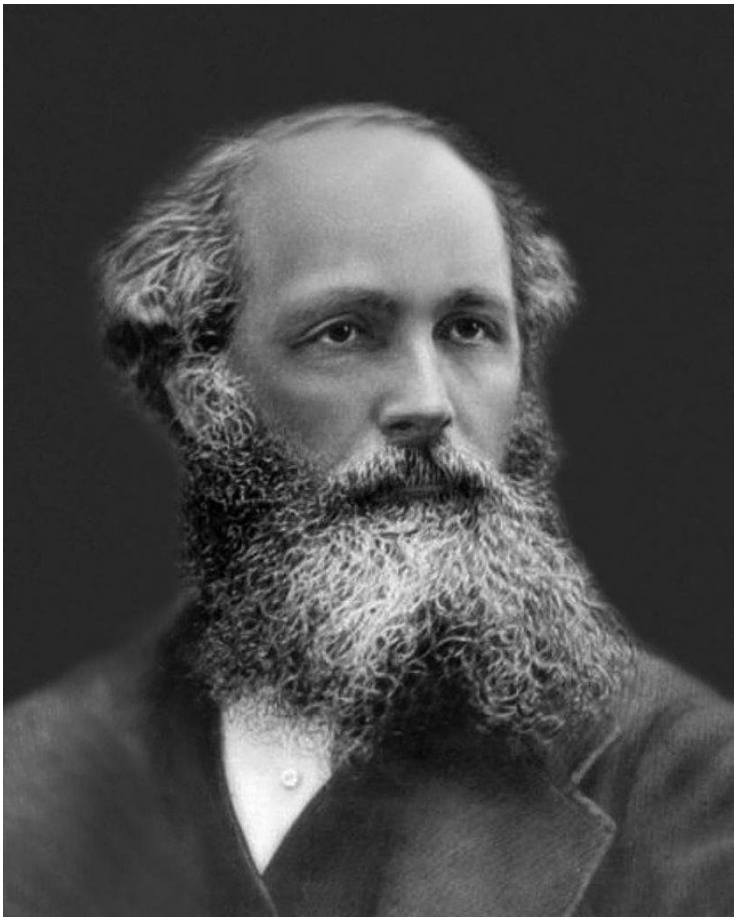
LL.D. EDIN., F.R.SS. L. & E.

*Professor of Experimental Physics in the University of Cambridge.*

*SECOND EDITION.*

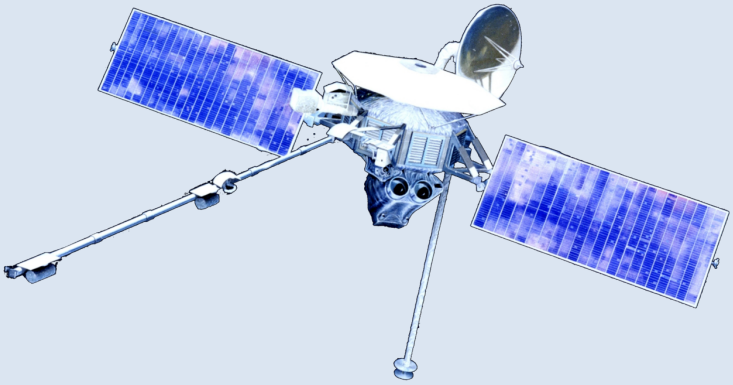
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DI PAVIA

LONDON:
LONGMANS, GREEN, AND CO.
1872.





**"The Theory of Heat"** is a book written by **James Clerk Maxwell** and published in 1871. The book is a comprehensive study of the laws of thermodynamics and their applications, and it is considered to be one of the most important works in the **field of thermodynamics**. **Maxwell** was a Scottish physicist and mathematician who made significant contributions to the fields of electromagnetism and thermodynamics. In **"The Theory of Heat",** he presented a unified view of the **laws of thermodynamics**, which describe the relationships between heat, energy, and work. The book is divided into four parts, each of which covers a different aspect of thermodynamics. **Part I** introduces the basic concepts of temperature, heat, and energy, and explains the laws of thermodynamics. **Part II** discusses the properties of gases and the behavior of gases under different conditions. **Part III** covers the theory of thermodynamic potentials and the concept of entropy. **Part IV** discusses the applications of thermodynamics, including heat engines and the theory of radiation. **Maxwell's work on thermodynamics** was highly influential, and **"The Theory of Heat"** played a key role in establishing the field as a rigorous science. The book is still widely read and studied today by physicists, engineers, and students of thermodynamics.





## The Mariner 10 probe

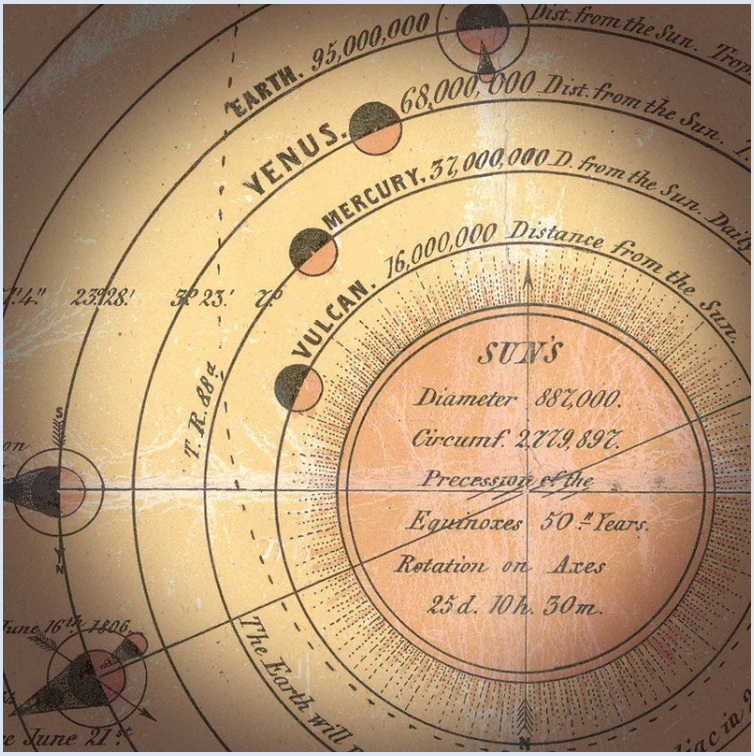
**(The first spacecraft sent to the planet Mercury)**

## Raymond Arthur Lyttleton's model on the formation of the Solar System

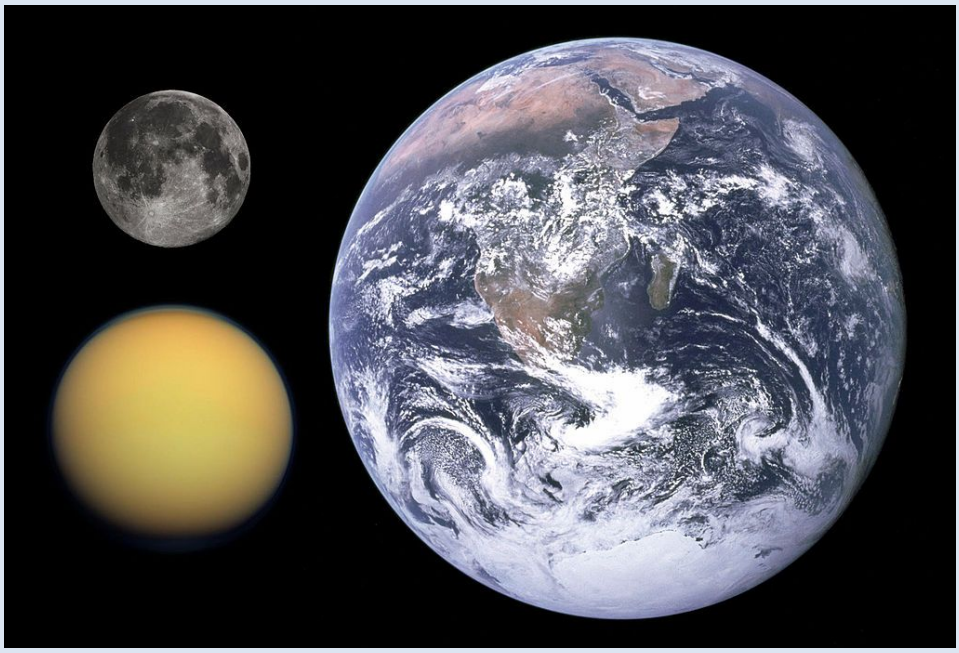
Raymond Arthur Lyttleton was a British mathematician and theoretical astronomer who proposed a model for the formation of the solar system in 1953. The model is known as the **tidal theory of solar system formation**. According to Lyttleton's model, the sun and the planets were formed from the tidal interaction between a passing star and a pre-existing cloud of gas and dust. As the star approached the cloud, its gravitational pull caused tidal forces to act on the cloud, compressing it and causing it to collapse under its own gravity. This collapse led to the formation of the sun and the protoplanetary disk that eventually gave rise to the planets. Lyttleton's model was unique in that it explained the formation of both the sun and the planets in a single process. However, the model was later found to be inconsistent with certain observations, such as the fact that the planets are all in nearly circular orbits. Nonetheless, **Lyttleton's contributions** to the field of astronomy, including his work on the physics of meteorites and comets, continue to be remembered and studied today.

## ✓ Fred Hoyle's model on Solar System formation

Fred Hoyle was a British astronomer who proposed a model for the formation of the solar system in the mid-20th century. Hoyle's model was known as the accretion theory. According to Hoyle's accretion theory, the sun and planets were formed from the gravitational collapse of a cloud of gas and dust. The collapse led to the formation of a protostar at the center of the cloud, which eventually became the sun. As the cloud collapsed further, it flattened into a disk-shaped structure, called a protoplanetary disk, which gave rise to the planets. Hoyle's model emphasized the importance of dust particles in the protoplanetary disk, which he believed would have clumped together to form planetesimals. These planetesimals would then have collided and stuck together, eventually forming the planets we observe today. Hoyle's accretion theory is still widely studied today, and it has been refined and modified over time to account for new observations and discoveries. While it is no longer the dominant theory of solar system formation, Hoyle's work remains an important contribution to our understanding of the origins of the solar system.

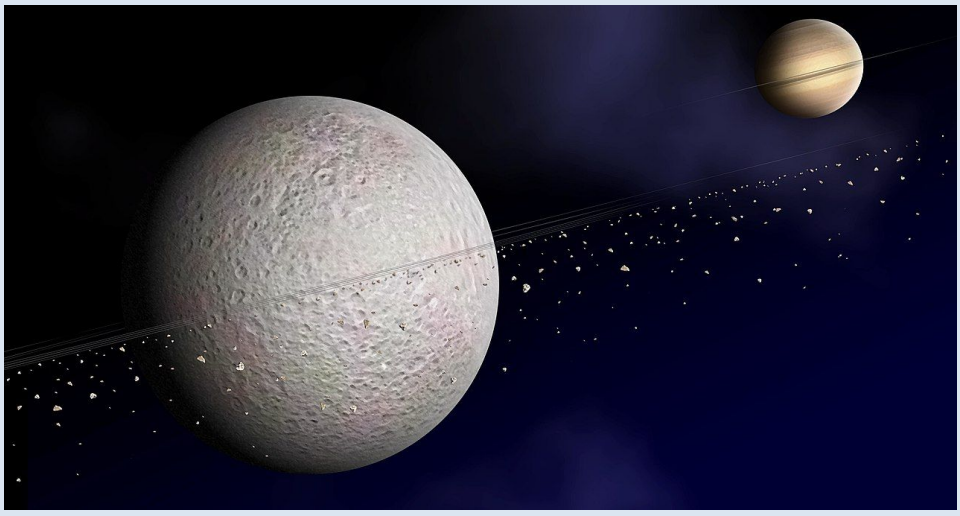



**A lithographic map of the solar system from 1846 shows the hypothetical planet Vulcan circling the sun at a near distance.**



**Titan** (lower left) with the **Moon** and **Earth** (top and right)

The largest moon of Saturn and the second largest moon in our solar system



**Artist's conception of rings around Rhea**

The second-largest moon of Saturn and the ninth-largest moon in our Solar System

## Subsatellite

A **subsatellite** is a smaller satellite that is placed into orbit around a larger satellite or planetary body. The term **"subsatellite"** typically refers to a secondary satellite that is deployed from a larger parent satellite, and is designed to perform specific scientific, operational, or technological tasks. **Subsatellites** are often used in space missions to perform tasks such as remote sensing, atmospheric measurements, or the testing of new technologies. They are an important tool for scientific research and technological development in space exploration.

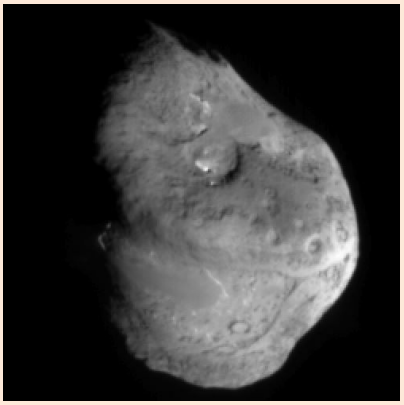


**The Voyager 2 spacecraft**

**(The only spacecraft that has ever been to Neptune and Uranus)**



**A depiction of the dwarf planet Makemake by an artist, showing its reddish surface and its moon**



**Tempel 1**



**Wilhelm Tempel**

**Tempel 1 is a comet in our solar system that orbits the Sun once every 5.5 years. It was discovered by Wilhelm Tempel in 1867 and is named after him.**

**Most massive stars have the shortest lifetimes — they have a lot of fuel but burn it at a very rapid pace.**

**Small red dwarfs burn their fuel extremely slowly and have lifetimes of a trillion years or more.**

## Stefan-Boltzmann Law:

**Hotter stars emit more!**

**Larger stars emit more!**

"Who would not have been laughed at if he had said in 1800 that metals could be extracted from their ores by electricity or that portraits could be drawn by chemistry.

{Commenting on Henri Becquerel's process for extracting metals by voltaic means.}"




**Michael Faraday**

✓ The **law of radioactive decay** is a fundamental principle in nuclear physics that describes how unstable atomic nuclei undergo a spontaneous transformation, or decay, to form more stable nuclei. This decay is characterized by the emission of radiation, such as alpha particles, beta particles, or gamma rays. The rate at which a radioactive substance decays is proportional to the amount of the substance present. This is known as the **exponential decay law**, and it can be expressed mathematically as:

$$N = N_0 \, e^{-\lambda t}$$

where N is the amount of the radioactive substance at time t, $N_0$ is the amount of the radioactive substance at time t = 0, e is the mathematical constant approximately equal to 2.71828 and λ is the decay constant (which is a characteristic property of the radioactive substance). **To understand this formula better, let's work through an example.**

Suppose we have a sample of 100 grams of a radioactive isotope with a decay constant of λ = 0.02 per day. How much of the isotope will remain after 10 days?

$$N = 100 \, e^{-(0.02 \times 10)}$$

$$N = 100 \, e^{-(0.2)}$$

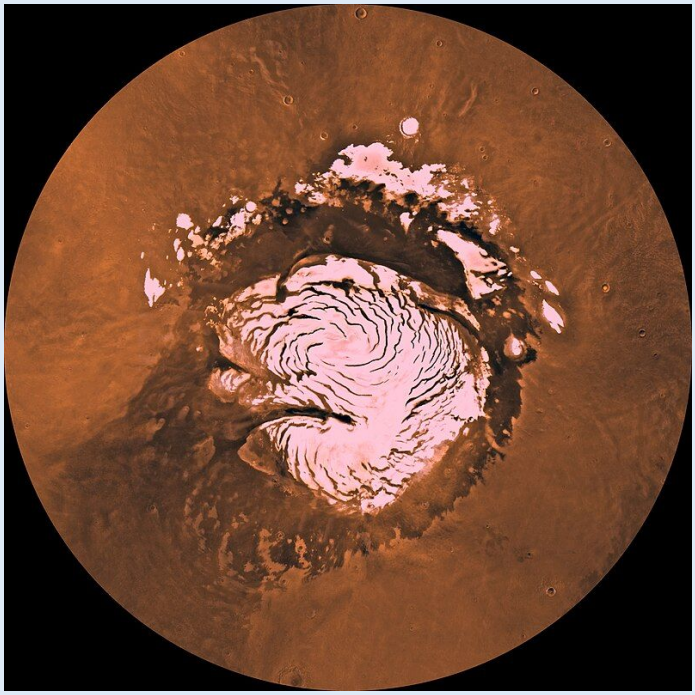
$$N = 100 \times 0.81873)$$

$$N = 81.873 \text{ grams}$$

Therefore, after 10 days, only 81.873 grams of the radioactive isotope will remain. The other 18.126 grams will have decayed and transformed into other, more stable elements.

## ✓ Areography

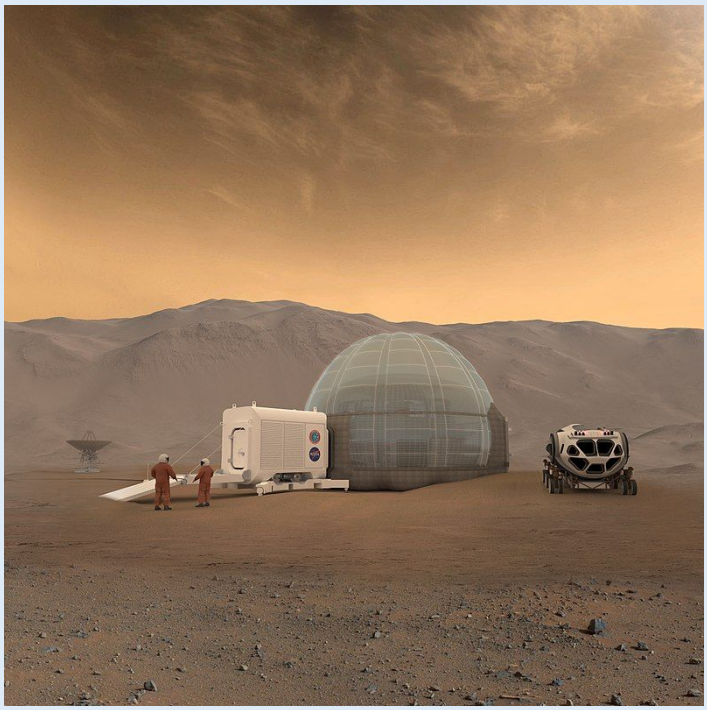
The branch of planetary science and geography that specifically focuses on the exploration and examination of Mars' surface features, geological formations, and physical characteristics.



The **North Polar Region of Mars** is covered by an ice cap, which is a prominent feature observed on the planet's surface.

## Chemical gardening

A chemistry experiment where metal salts like **copper sulphate** or **cobalt (II) chloride** are added to an aqueous solution of sodium silicate. This leads to the rapid formation of plant-like structures within minutes to hours.



In 2016, a concept for a **Mars base** was proposed, incorporating **three essential components**: an "ice home," a pressurized rover, and Mars suits. The **"ice home"** would utilize Martian ice as a building material to create a habitat for astronauts. The **pressurized rover** would allow for exploration of the Martian surface while providing a safe environment for astronauts during their journeys. Additionally, specialized **Mars suits** would be designed to protect astronauts from the harsh Martian conditions, ensuring their safety during extravehicular activities. This concept aimed to facilitate sustainable human presence and exploration on the red planet.



**Illustration of a major impact event:** When an asteroid with a few kilometres in diameter collides with a larger body such as the Earth, the energy released is equivalent to several million nuclear warheads detonating at the same time.

$$T_{then} = T_{now} (1+z)$$



**Since energy density of radiation (u) $\propto T^4$:**

$$u_{then} = u_{now} (1+z)^4$$



**For z = 0.5:**

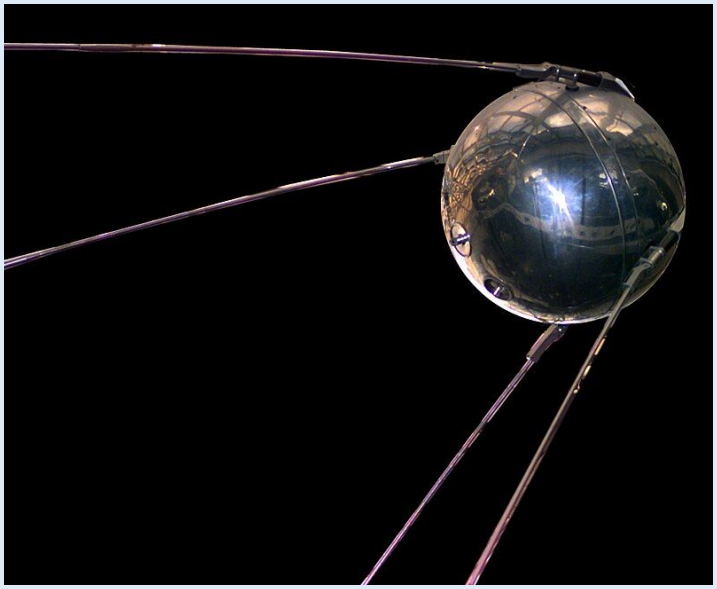
$$u_{then} = u_{now} (1+0.5)^4$$

$$u_{then} = 5.0625\ u_{now}$$

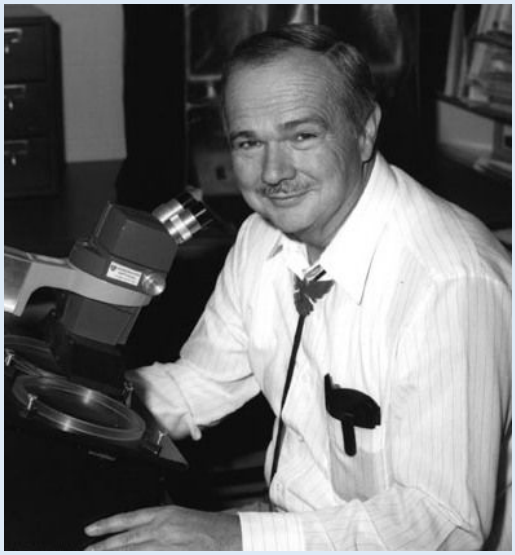
The energy density of radiation was approximately 5.0625 times higher in the past compared to the present.

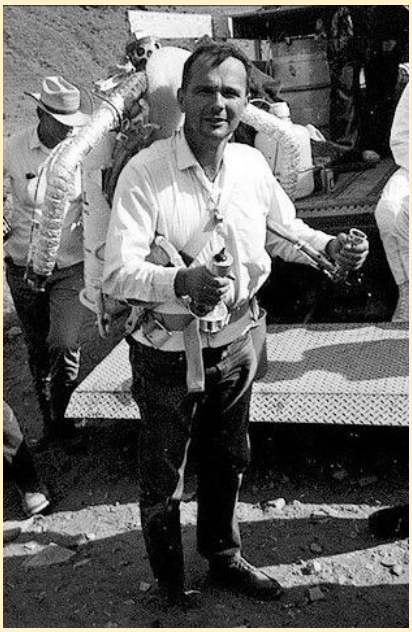
✓ **Space Race**

The intense competition between the United States and the Soviet Union during the Cold War era to achieve milestones in space exploration



A replica of **Sputnik 1**, the pioneering artificial satellite that was the first to be launched into outer space, stored in the **National Air and Space Museum.**



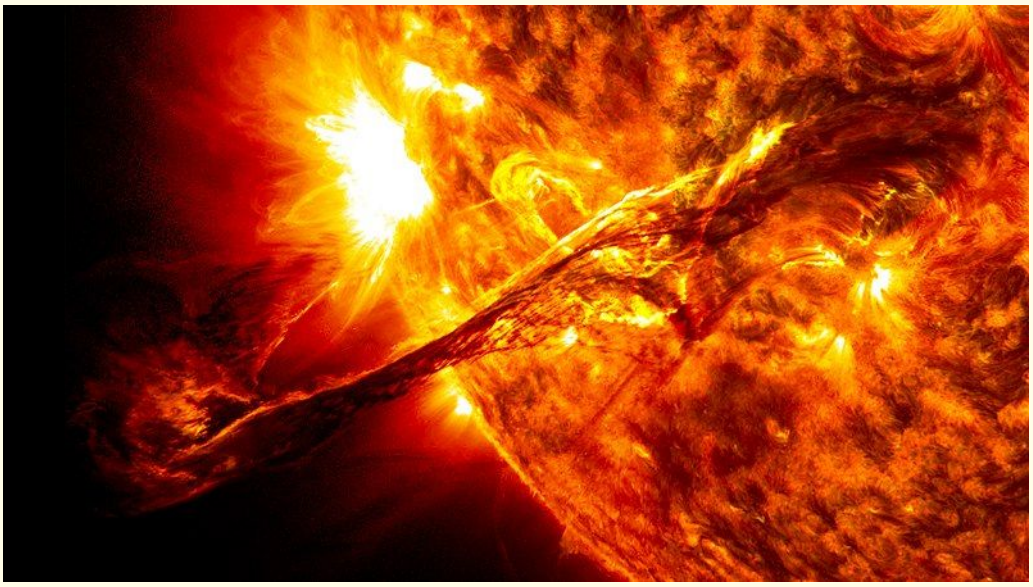


**Eugene Shoemaker** wearing a Bell Rocket Belt while training astronauts.

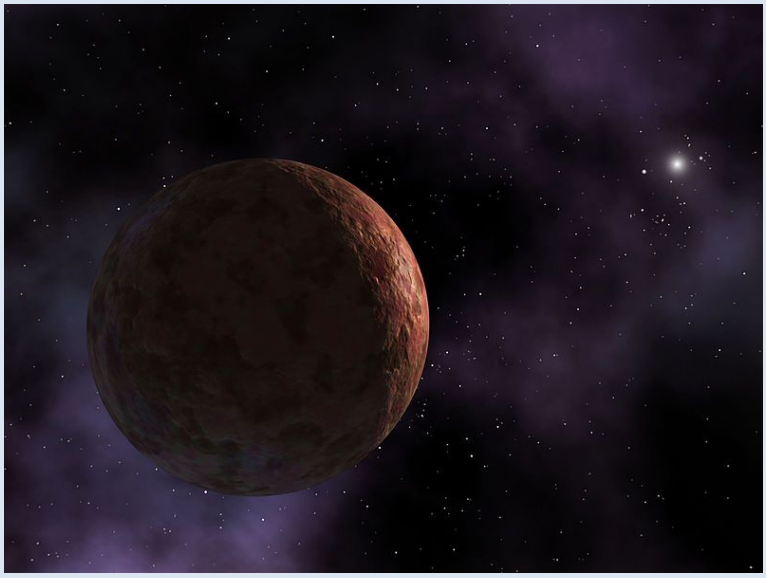
**Eugene Merle Shoemaker** was the first to provide evidence supporting the idea that meteorite impacts have affected the Earth.



**Spirograph Nebula** (IC 418) captured by **the Hubble Space Telescope's Wide Field Planetary Camera 2**.



A **giant prominence** on the sun erupted on August 31, 2012, blasting particles and creating a shock wave that passed close to Earth.



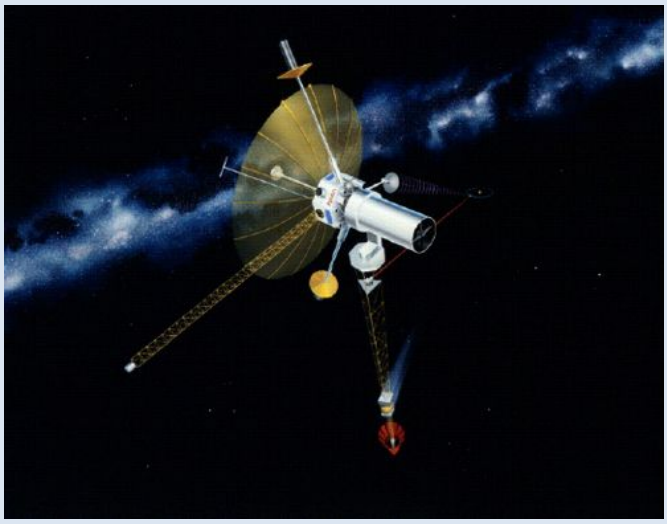
**An image of Sedna created by an artist. Sedna is reddish in colour.**

**A dwarf planet located in the outer reaches of our solar system, approximately 11 billion miles (17.7 billion kilometers) from the Sun**



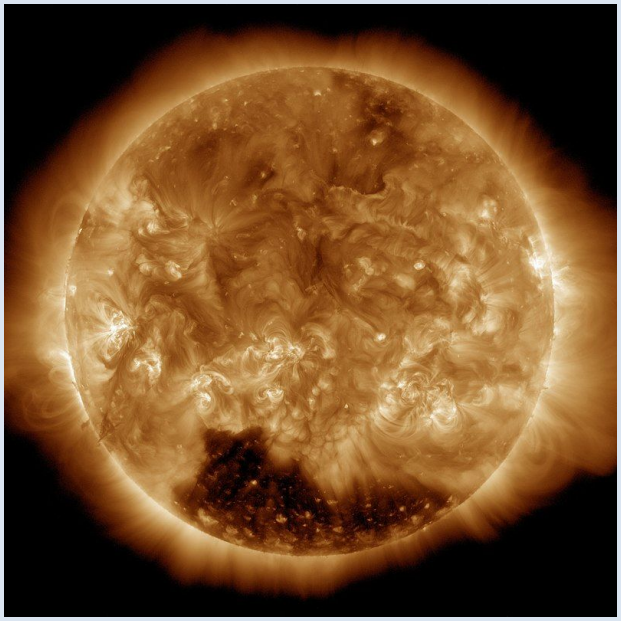
**225088 Gonggong as imagined by the artist, with its rosy surface.**

**A trans-Neptunian object (TNO) and a possible dwarf planet in the Kuiper Belt, a region of the solar system beyond Neptune.**



**Artist's impression of the TAU (Thousand Astronomical Units) spacecraft**

A projected robotic interstellar probe by **NASA/JPL** in 1987 that would use validated technology to travel to a distance of **1000 astronomical units** (1000 AU) beyond the Earth and Sun



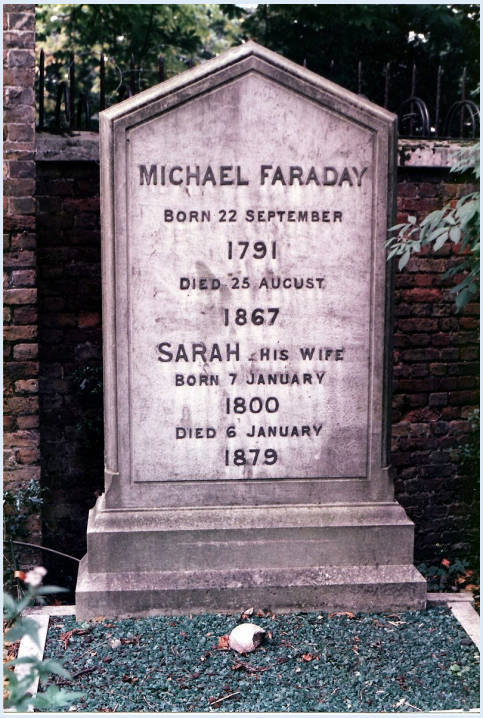
✓ **Solar Dynamics Observatory image of the Sun taken at 19.3 nanometers**

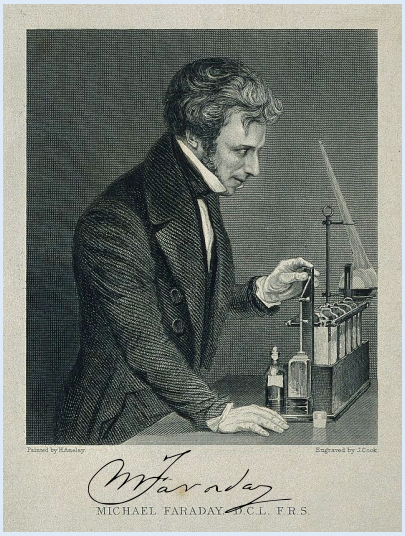


**Pioneer H, a cancelled probe to investigate the Sun, is on display at the National Air and Space Museum.**

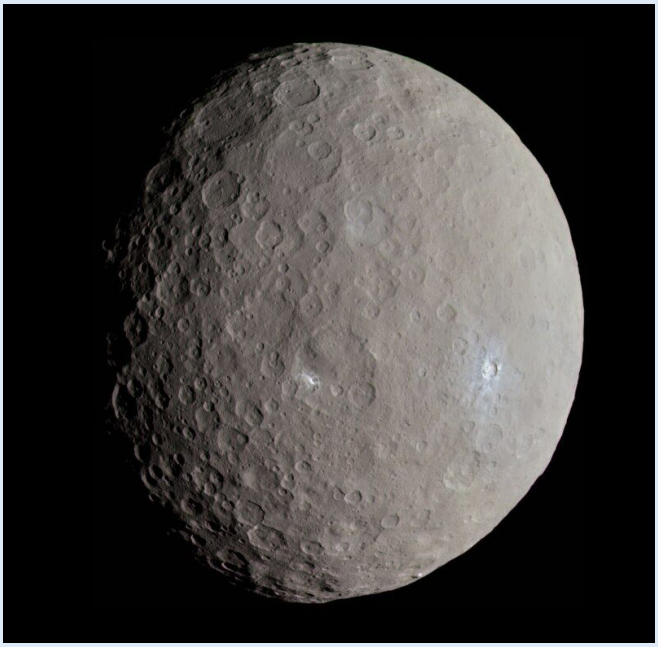
## Did you know?

Astronomers have discovered some of the oldest known stars in the Milky Way galaxy that are estimated to be almost 13.6 billion years old. These stars are known as "**methuselah stars**" or "**primitive stars,**" and they are believed to have formed shortly after the Big Bang.



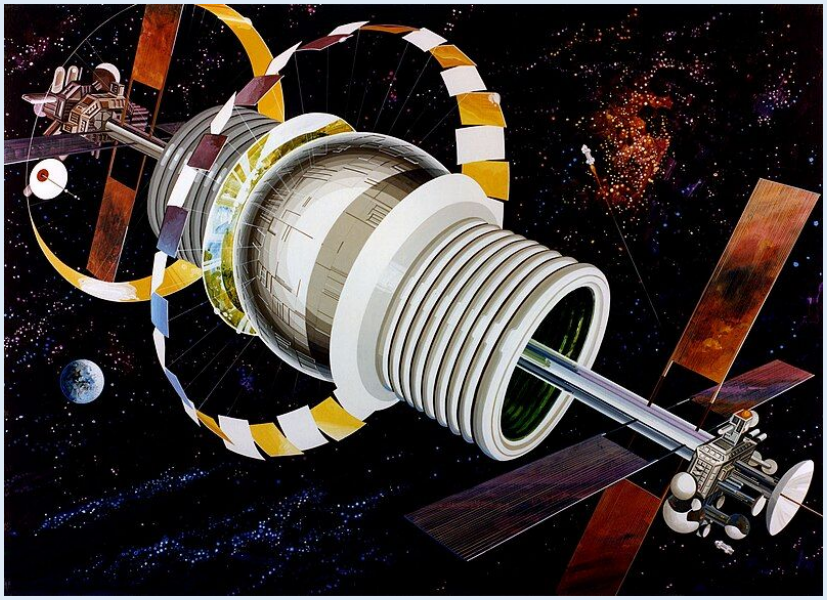

**Faraday's grave at Highgate Cemetery, London**



**Ceres, the largest object in the asteroid belt situated between Mars and Jupiter, holds the distinction of being the only dwarf planet found within the inner solar system. With a diameter of approximately 590 miles (950 kilometers), it was previously designated as a planet before undergoing reclassification as an asteroid and eventually recognized as a dwarf planet.**

## ✓ Bernal sphere

A type of space habitat designed to provide a self-sufficient living environment for human population for centuries and offer a potential solution to the problem of long-term space colonization, first proposed in 1929 by **John Desmond Bernal**.



**Artistic depiction of the exterior view of a Bernal sphere space habitat design.**



**Artistic depiction of the interior view of a Bernal sphere space habitat design.**



**A Bernal sphere next to a solar power satellite and an asteroid mining station**

## ✓ Rotating wheel space station

Also known as a **von Braun wheel**, was initially introduced by **Konstantin Tsiolkovsky** in 1903 and later elaborated upon by **Herman Potočnik** in 1929. It is a hypothetical wheel shaped space station that rotates about its axis, thus creating an environment of artificial gravity. The occupants of the station would experience centripetal acceleration given by:

$$a = -\omega^2 r$$

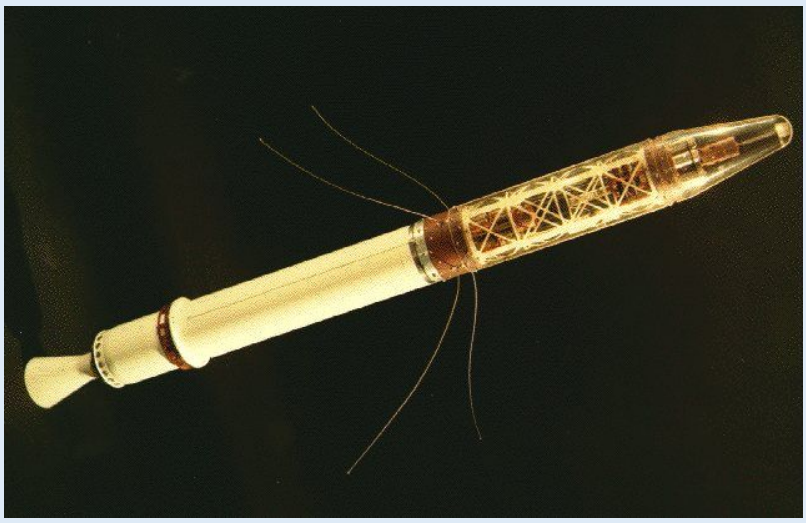
where $\omega$ is the angular velocity of the station and $r$ is its radius. The **negative sign** indicates that the acceleration is directed towards the center of the station. This centrifugal acceleration mimics the effects of gravity, allowing inhabitants to live and work in a more familiar and comfortable manner during extended stays in space.



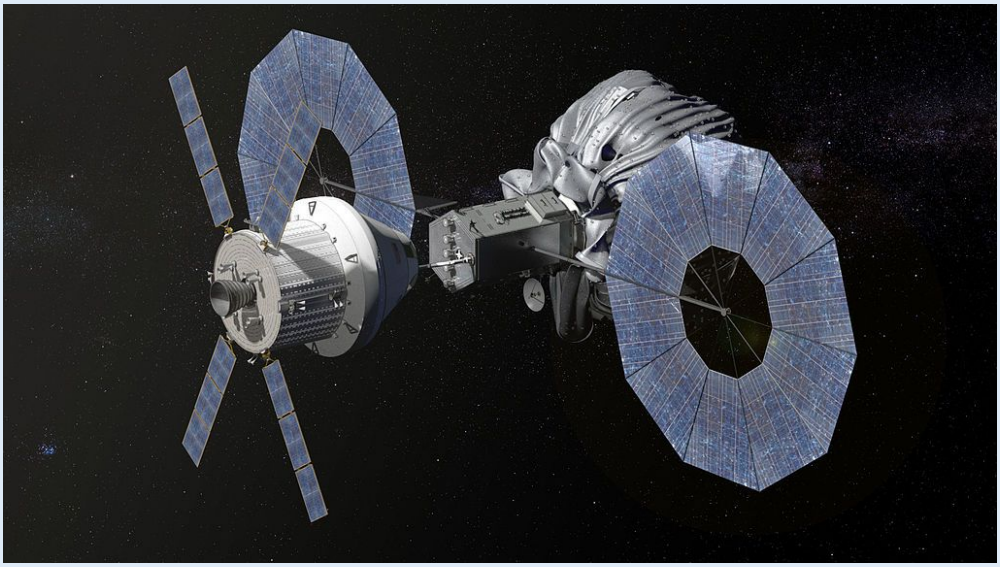

**This is an illustration of von Braun's 1952 space station proposal.**

## Planetary chauvinism

The belief that human society will always remain primarily planet-based and may ignore the potential benefits of space-based living. This perspective assumes that Earth will always be the central and most significant location for human civilization, even if we expand our presence beyond our home planet.



A replica of **Explorer 1**, the first successful American satellite launched into space. It was part of the U.S. response to the Soviet Union's launch of Sputnik 1, which marked the beginning of the space age.



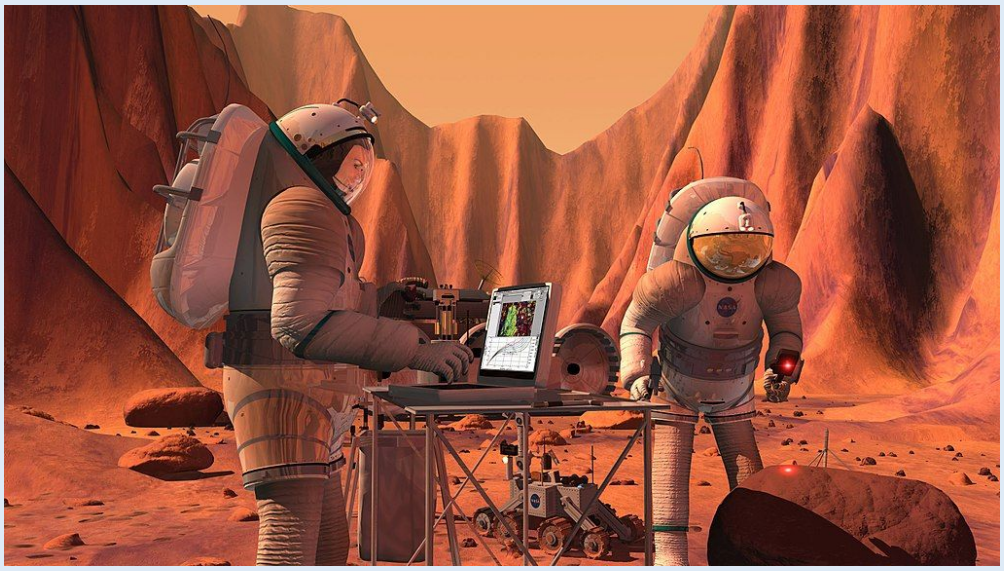
This illustration depicts NASA's envisioned **Orion spacecraft** as it approaches a robotic asteroid capture vehicle.

## Space advocacy

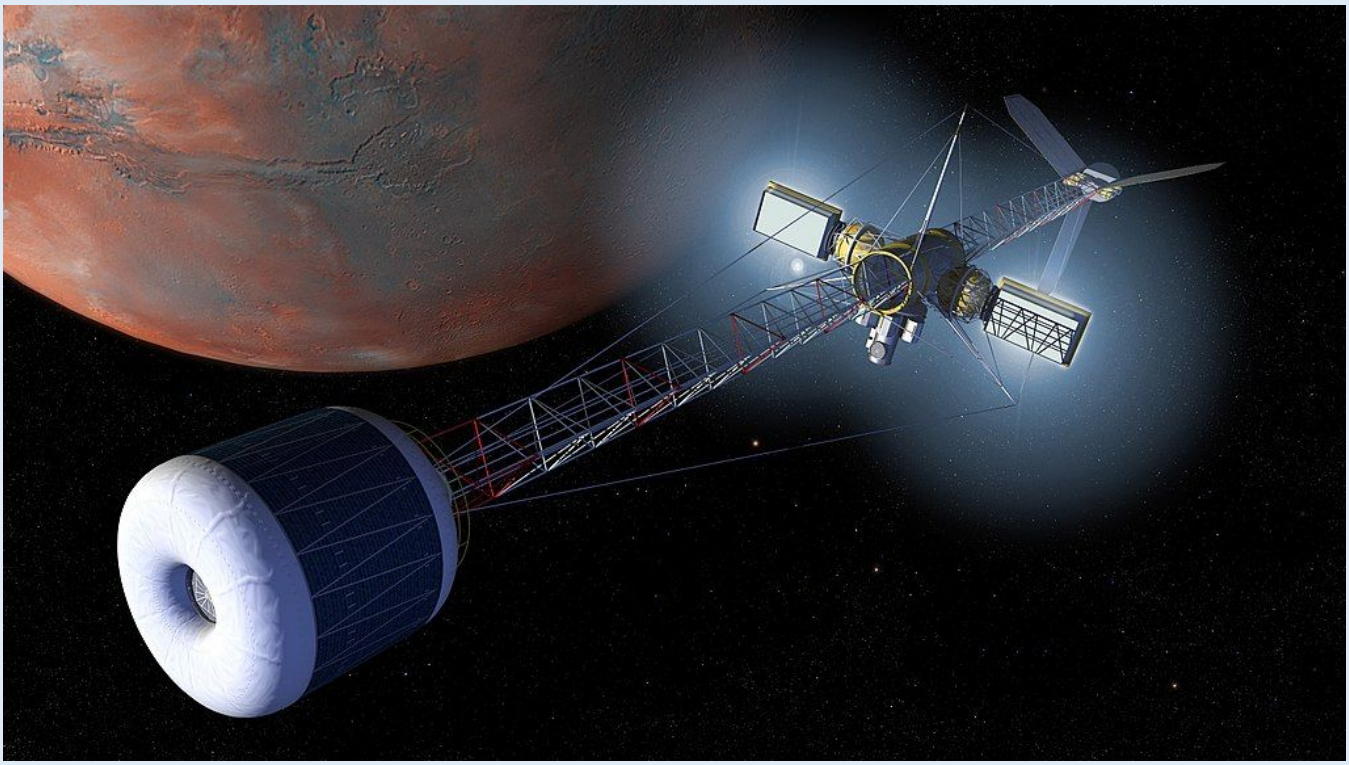
The active promotion and support of space exploration, space science, and related activities. It involves individuals, organizations, and communities advocating for increased funding, public awareness, and policy support for space missions, research, and development.




This depiction presents an artist's vision of the **NASA's Lockheed Martin Single-Stage-To-Orbit (SSTO) Reusable Launch Vehicle (RLV)** positioned in orbit high above the Earth.



This is a NASA depiction of a crew on Mars conducting an analysis of a sample.



This artistic representation illustrates potential activities for future space exploration missions, featuring a **Mars Artificial Gravity Transfer Vehicle**.

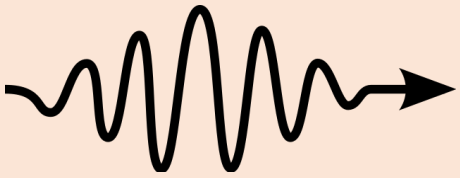
✓ **Gravitational time dilation** is a phenomenon predicted by **Albert Einstein's theory of general relativity**, which states that time runs slower in a region of stronger gravitational field. This means that time moves slower for an observer who is closer to a massive object such as a planet, star or black hole, than an observer who is farther away. It can be quantified with the equation:

$$T = \frac{T_0}{\sqrt{1-\frac{2GM}{rc^2}}}$$

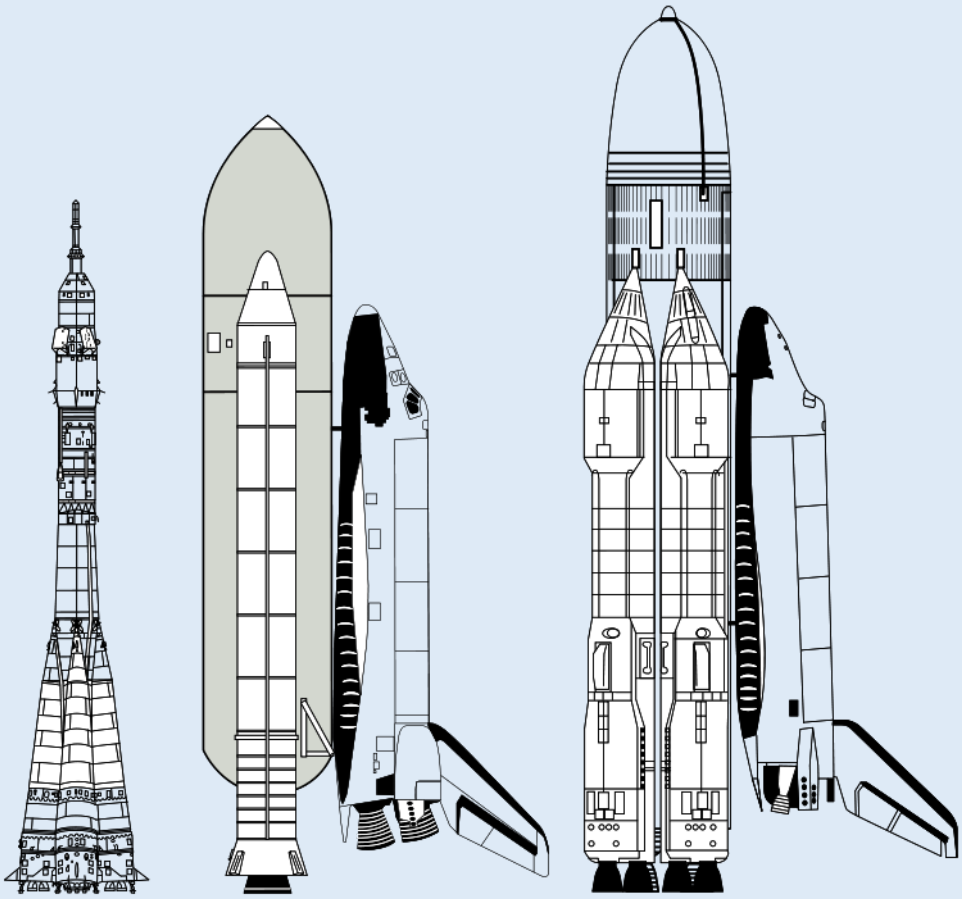
The time measured by an observer located at a distance **"r"** from the center of a massive object of mass **"M"**

The time experienced by an observer located on the surface of the massive object

This equation implies that the **time dilation effect** increases as the **gravitational field** becomes stronger. In other words, time runs slower near massive objects such as black holes or in regions of stronger gravitational fields.



| | |
|---|---|
| ✓ $r = \frac{3GM}{c^2}$ | $T = \sqrt{3}\, T_0 \approx 1.732\, T_0$ |
| ✓ $r = \frac{2GM}{c^2}$ | $T \to \infty$ |
| ✓ $r < \frac{2GM}{c^2}$ | $T \to$ imaginary |



The **Soyuz rocket** is depicted on the left, the **Space Shuttle** in the center, and the **Energia-Buran** on the right (all drawn to scale). These are the rockets currently utilized for launching **manned spacecraft** (a type of space vehicle designed to carry human astronauts or cosmonauts into space) into orbit.




This is an **USSR stamp** featuring cosmonauts **Georgy Dobrovolsky**, **Vladislav Volkov**, and **Viktor Patsayev**, part of the "In Memory of Cosmonauts" series, commemorating their death during the **"Soyuz 11"** space mission that took place from June 6 to June 30, 1971.

"Very few will remain in the shrine of science, if we eliminate those moved by ambition, calculation, of whatever personal motivations; one of them will be Max Planck."

**−Albert Einstein**

**Asteroids** are believed to be remnants from the early solar system, left over from the formation of planets. **Asteroids** can pose a potential threat to Earth if they collide with our planet. In fact, an asteroid impact is believed to have been responsible for the extinction of the **dinosaurs** about 66 million years ago.

Hawking's work on black holes showed that General relativity and Quantum mechanics contradict each other

**This puzzle is known as the Black Hole Information Paradox**

# 1899, John Smith Interview with Nikola Tesla

**John Smith:** Mr. Tesla, you have gained the glory of the man who got involved in the cosmic processes. Who are you, Mr. Tesla?

**Nikola Tesla:** It is a right question, Mr. Smith, and I will try to give you the right answer to it.

**John Smith:** Some say you're from the country of Croatia, from the area called Lika, where together with the people are growing trees, rocks and starry sky. They say that your home village is named after the mountain flowers, and that the house, where you were born, is next to the forest and the church.

**Nikola Tesla:** Really, all it true. I'm proud of my Serbian origin and my Croatian homeland.

**John Smith:** Futurists say that the Twenty-and Twenty First Century was born in head of Nikola Tesla. They celebrate conversely magnetic field and sing hymns to Inductions engine. Their creator was called the hunter who caught the light in his net from the depths of the earth, and the warrior who captured fire from heaven. Father of alternating current will make the Physics and Chemistry dominate half the world. Industry will proclaim him as their supreme saint, a banker for the largest benefactors. In the laboratory of Nikola Tesla for the first time is broken atom.

There is created a weapon that causes the earthquake vibrations. There are discovered black cosmic rays. Five races will pray to him in the Temple of the future, because they had taught a great secret that Empedocles elements can be watered with the life forces from the ethers.

**Nikola Tesla:** Yes, these are some of my most important discoveries. I'm a defeated man. I have not accomplished the greatest thing I could.

**John Smith:** What is it, Mr. Tesla?

**Nikola Tesla:** I wanted to illuminate the whole earth. There is enough electricity to become a second sun. Light would appear around the equator, as a ring around Saturn.

Mankind is not ready for the great and good. In Colorado Springs I soaked the earth by electricity. Also we can water the other energies, such as positive mental energy. They are in the music of Bach or Mozart, or in the verses of great poets. In the Earth's interior, there are energy of Joy, Peace and Love. Their expressions are a flower that grows from the Earth, the food we get out of her and everything that makes man's homeland. I've spent years looking for the way that this energy could influence people. The beauty and the scent of roses can be used as a medicine and the sun rays as a food.

Life has an infinite number of forms, and the duty of scientists is to find them in every form of matter. Three things are essential in this. All that I do is a search for them. I know I will not find them, but I will not give up on them.

**John Smith:** What are these things?

**Nikola Tesla:** One issue is food. What a stellar or terrestrial energy to feed the hungry on Earth? With what wine watered all thirsty, so that they can cheer in their heart and understand that they are Gods?

Another thing is to destroy the power of evil and suffering in which man's life passes! They sometimes occur as an epidemic in the depths of space. In this century, the disease had spread from Earth in the Universe.

The third thing is: Is there an excess Light in the Universe? I discovered a star that by all the astronomical and mathematical laws could disappear, and that nothing seems to be modified. This star is in this galaxy. Its light can occur in such density that fits into a sphere smaller than an apple, a heavier than our Solar System. Religions and philosophies teach that man can become the Christ, Buddha and Zoroaster. What I'm trying to prove is wilder, and almost unattainable. This is what to do in the Universe so every being is born as Christ, Buddha or Zoroaster.

I know that gravity is prone to everything you need to fly and my intention is not to make flying devices (aircraft or missiles), but teach individual to regain consciousness on his own wings … Further; I am trying to awake the energy contained in the air. There are the main sources of energy. What is considered as empty space is just a manifestation of matter that is not awakened.

No empty space on this planet, nor in the Universe.. In black holes, what astronomers talk about, are the most powerful sources of energy and life.

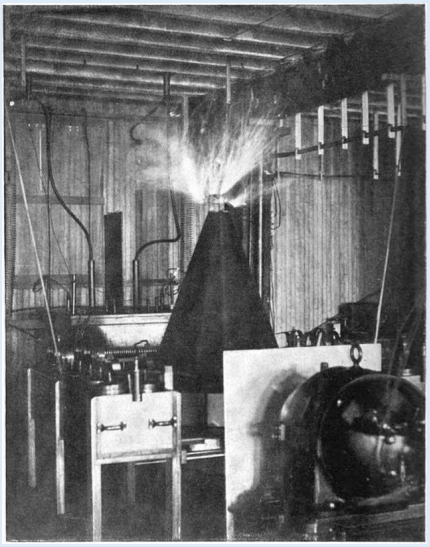
**John Smith:** On the window of your room in hotel "**Valdorf-Astoria**", on the thirty-third floor, every morning, the birds arrive.



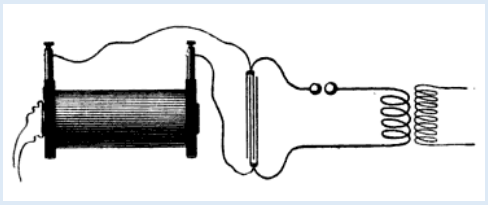
Badge and Ribbon of Order of Danica Hrvatska with the face of **Nikola Tesla**.




A bust of **Nikola Tesla** in an engineering building at Yale University.



An early **Tesla coil** constructed by **Nikola Tesla** at his laboratory at 35 South Fifth Ave., New York around 1895.



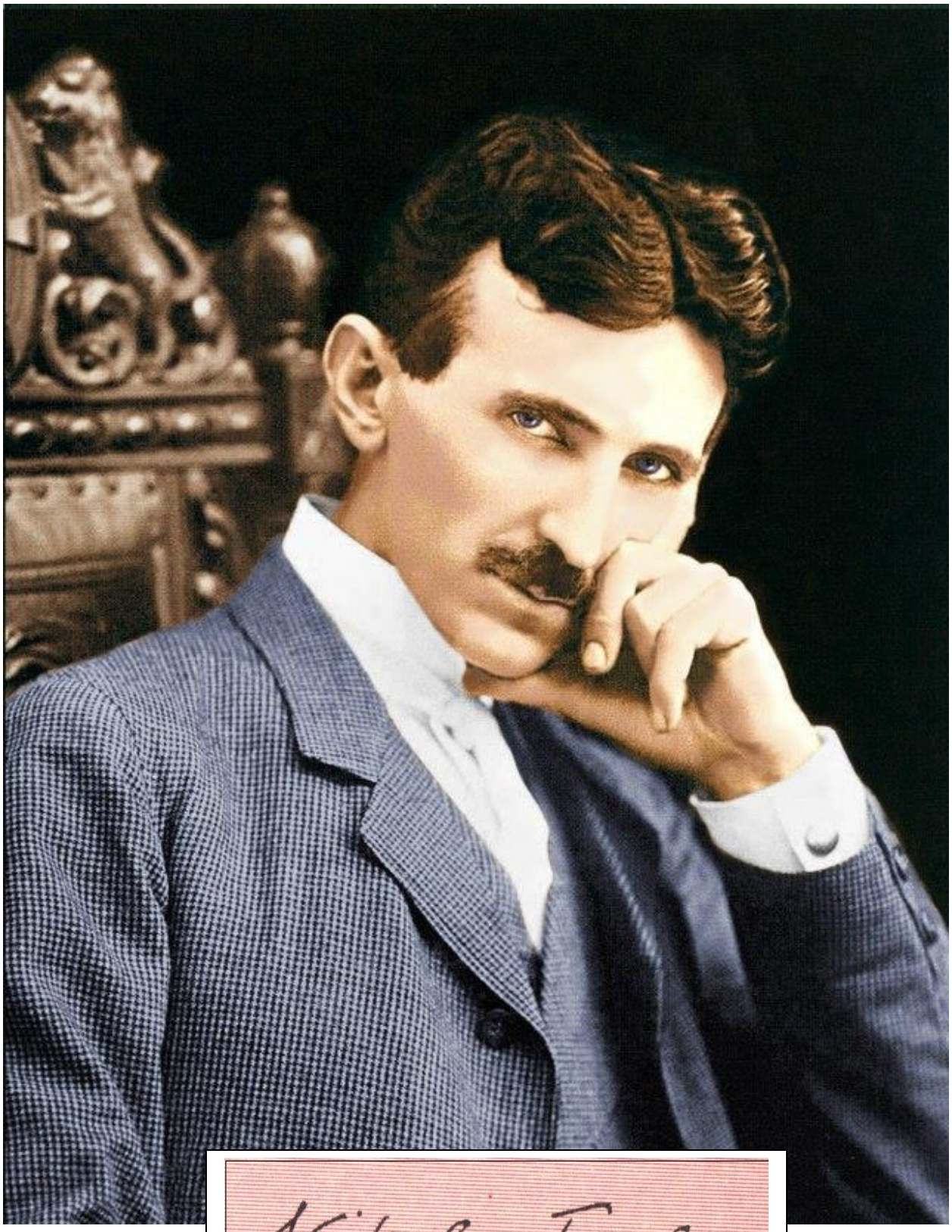
One of the first drawings of a **Tesla coil circuit**, an illustration used by **Nikola Tesla** in his May 20, 1891 lecture **Experiments with Alternate Currents of Very High Frequency and Their Application to Methods of Artificial Illumination** before the American Institute of Electrical Engineers at Columbia College, New York.



Nikola Tesla's Wardenclyffe wireless station, located in Shoreham, New York, seen in 1904.



**X-Ray Photograph of Nikola Tesla's left hand**


Nikola Tesla

**Nikola Tesla:** A man must be sentimental towards the birds. This is because of their wings. Human had them once, the real and visible!

**John Smith:** You have not stopped flying since those distant days in Smiljan!

**Nikola Tesla:** I wanted to fly from the roof and I fell: Children's calculations could be wrong. Remember, the youth wings have everything in life!

**John Smith:** Have you ever married? It is not known that you have affection for love or for a woman. Photos from the youth show you were handsome man.

**Nikola Tesla:** Yes. I did not. There are two views: a lot affection or not at all. The center serves to rejuvenate human race. Women for certain people nurtures and strengthen its vitality and spirit. Being single does the same to other people. I chose that second path.

**John Smith:** Your admirers are complaining that you attacking relativity. The strange is your assertion that the matter has no energy. Everything is imbued with energy, where it is?

**Nikola Tesla:** First was energy, then matter.

**John Smith:** Mr. Tesla, it's like when you said that you were born by your father, and not on you.

**Nikola Tesla:** Exactly! What about the birth of the Universe? Matter is created from the original and eternal energy that we know as Light .It shone, and there have been appear star, the planets, man, and everything on the Earth and in the Universe. Matter is an expression of infinite forms of Light, because energy is older than it. There are four laws of Creation. The first is that the source of all the baffling, dark plot that the mind cannot conceive, or mathematics measure. In that plot fit the whole Universe.



The second law is spreading a darkness, which is the true nature of Light, from the inexplicable and it's transformed into the Light. The third law is the necessity of the Light to become a matter of Light. The fourth law is: no beginning and no end; three previous laws always take place and the Creation is eternal.

**John Smith:** In the hostility to the theory of relativity you go so far, that you hold lectures against its Creator at your birthday parties..

**Nikola Tesla:** Remember, it is not curved space, but the human mind which cannot comprehend infinity and eternity! If relativity has been clearly understood by its Creator, he would gain immortality, even yet physically, if he is pleased.

I am part of a light, and it is the music. The Light fills my six senses: I see it, hear, feel, smell, touch and think. Thinking of it means my sixth sense. Particles of Light are written note. O bolt of lightning can be an entire sonata. A thousand balls of lightening is a concert.. For this concert

I have created a Ball Lightning, which can be heard on the icy peaks of the Himalayas.

About Pythagoras and mathematics a scientist may not and must not infringe of these two. Numbers and equations are signs that mark the music of the spheres. If Einstein had heard these sounds, he would not create theories of relativity. These sounds are the messages to the mind that life has meaning, that the Universe exists in perfect harmony, and its beauty is the cause and effect of Creation. This music is the eternal cycle of stellar heavens.

The smallest star has completed composition and also, part of the celestial symphony. The man's heartbeats are part of the symphony on the Earth. Newton learned that the secret is in geometric arrangement and motion of celestial bodies. He recognized that the supreme law of harmony exists in the Universe. The curved space is chaos, chaos is not music. Einstein is the messenger of the time of sound and fury.

**John Smith:** Mr. Tesla, do you hear that music?

**Nikola Tesla:** I hear it all the time. My spiritual ear is as big as the sky we see above us. My natural ear I increased by the radar. According to the Theory of Relativity, two parallel lines will meet in infinity. By that Einstein's curved will straighten. Once created, the sound lasts forever. For a man it can vanish, but continues to exist in the silence that is man's greatest power.

No, I have nothing against Mr. Einstein. He is a kind person and has done many good things, some of which will become part of the music. I will write to him and try to explain that the ether exists, and that its particles are what keep the Universe in harmony, and the life in eternity.

**John Smith:** Tell me, please, under what conditions Angel adopt on the Earth?

**Nikola Tesla:** I have ten of them. Keep good records vigilant.

**John Smith:** I will document all your words, Dear Mr. Tesla.

**Nikola Tesla:** The first requirement is a high awareness of its mission and work to be done. It must, if only dimly, exist in the early days. Let us not be falsely modest; Oak knows that it is oak tree, a bush beside him being a bush. When I was twelve, I have been sure I will get to Niagara Falls. For most of my discoveries I knew in my childhood that I will achieve them, although not entirely apparent … The second condition to adapt is determination. All that I might, I finished.

**John Smith:** What is the third condition of adjustment, Mr. Tesla?

**Nikola Tesla:** Guidance for all the vital and spiritual energies in labor. Therefore purification of the many effects and needs that man has. I therefore have not lost anything, but just gained.

So I enjoyed every day and night. Write down: Nikola Tesla was a happy man… The fourth requirement is to adjust the physical assembly with a work.

✓ **John Smith:** What do you mean, Mr. Tesla?

**Nikola Tesla:** First, the maintenance of the assembly. Man's body is a perfect machine. I know my circuit and what's good for him. Food what nearly all people eat, to me it is harmful and dangerous. Sometimes I visualize that chefs in the world are all in conspiracy against me … Touch my hand.

✓ **John Smith:** It was cold.

**Nikola Tesla:** Yes. Bloodstream can be controlled, and many processes in and around us. Why are you frightened young man?

✓ **John Smith:** It's a story that Mark Twain wrote a mysterious stranger, that wonderful book of Satan, inspired by you.

**Nikola Tesla:** The word "**Lucifer**" is more charming. Mr. Twain likes to joke. As a child I was healed once by reading his books. When we met here and told him about, he was so touched that he cried. We became friends and he often came to my lab. Once he requested to show him a machine that by vibration provokes a feeling of bliss. It was one of those inventions for entertainment, what I sometimes like to do.

I warned Mr. Twain as not to remain under these vibrations. He did not listen and stayed longer. It ended by being, like a rocket, holding pants, darted into a certain room. It was a diabolically funny, but I kept the seriousness.

But, to adjust the physical circuit, in addition to food, dream is very important. From a long and exhausting work, which required superhuman effort, after one hour of sleep I'd be fully recovered. I gained the ability to manage sleep, to fell asleep and wake up in the time which I have designated. If I do something what I do not understand, I force myself to think about it in my dream, and thus find a solution.

**Nikola Tesla:** The fifth condition of adjustment is memory. Perhaps in the most people, the brain is keeper of knowledge about the world and the knowledge gained through the life. My brain is engaged in more important things than remembering, it is picking what is required at a given moment. This is all around us. It should only be consumed. Everything that we once saw, hear, read and learn, accompanies us in the form of light particles. To me, these particles are obedient and faithful.

Goethe's Faust, my favorite book, I learned by heart in German as a student, and now it can all recite. I held my inventions for years 'in my head', and only then I realized them.

✓ **John Smith:** You often mentioned the power of visualization.

**Nikola Tesla:** I might have to thank to visualization for all that I invented. The events of my life and my inventions are real in front of my eyes, visible as each occurrence or the item. In my youth I was frightened of not knowing what it is, but later, I learned to use this power as an exceptional talent and gift. I nurtured it, and jealously guarded. I also made corrections by visualization on most of my inventions, and finish them that way, by visualization I mentally solve complex mathematical equations. For that gift I have, I will receive rank High Lama in Tibet.

My eyesight and hearing are perfect and, dare to say, stronger than other people. I hear the thunder of a hundred fifty miles away, and I see colors in the sky that others cannot see. This enlargement of vision and hearing, I had as a child. Later I consciously developed.

**John Smith:** In youth you have several times been seriously ill. Is it a disease and a requirement to adapt?

**Nikola Tesla:** Yes. It is often the result of a lack of exhaustion or vital force, but often the purification of mind and body from the toxins that have accumulated. It is necessary that a man suffers from time to time. The source of most disease is in the spirit. Therefore the spirit and can cure most diseases. As a student I got sick of cholera which raged in the region of Lika. I was cured because my father finally allowed me to study technology, which was my life. Illusion for me was not a disease, but the mind's ability to penetrate beyond the three dimensions of the earth.

I had them all my life, and I have received them as all other phenomena around us. Once, in childhood, I was walking along the river with Uncle and said: "From the water will appear the trout, I'll throw a stone and it is cut." That's what happened. Frightened and amazed, his uncle cried: "Bade retro Satan's!" He was an educated and he spoke in Latin …

I was in Paris when I saw my mother's death. In the sky, full of light and music floated are wonderful creatures. One of them had a mother's character, who was looking at me with infinite love. As the vision disappeared, I knew that my mother died.

**John Smith:** What is the seventh adjustment, Mr. Tesla?

**Nikola Tesla:** The knowledge of how the mental and vital energy transform into what we want, and achieve control over all feelings. Hindus call it Kundalini Yoga. This knowledge can be learned, for what they need many years or is acquired by birth. The most of them I acquired by birth. They are in the closest connection with a sexual energy that is after the most widespread in the Universe. The woman is the biggest thief of that energy, and thus the spiritual power.

I've always knew that and was alerted. Of myself I created what I wanted: a thoughtful and spiritual machine.

**John Smith:** A ninth adjustment, Mr. Tesla?

**Nikola Tesla:** Do everything that any day, any moment, if possible, not to forget who we are and why we are on Earth. Extraordinary people who are struggling with illness, privation, or the society which hurts them with its stupidity, misunderstanding, persecution and other problems which the country is full of a swamps with insects, leaves behind unclaimed until the end of the work. There are many fallen angels on Earth.

**John Smith:** What is the tenth adaptation?

**Nikola Tesla:** It is most important. Write that Mr. Tesla played. He played the whole of his life and enjoyed it.

**John Smith:** Mr. Tesla! Whether it relates to your findings and your work? Is this a game?

**Nikola Tesla:** Yes, dear boy. I have so loved to play with electricity! I always cringe when I hear about the one also the Greek who stole fire. A terrible story about studding, and eagles peck at his liver. Did Zeus did not have enough lightning and thunder, and was damaged for one fervor? There is some misunderstanding…

Lightning are the most beautiful toys that can be found. Do not forget that in your text stand out: Nikola Tesla was the first man who discovered lightning.

**John Smith:** Mr. Tesla, you're just talking about angels and their adaptation to the Earth.

**Nikola Tesla:** Am I? This is the same. You could write this: he dared to take upon himself the prerogatives of Indri, Zeus and Peron. Imagine one of these gods in a black evening suit, with the bowler hat and wearing white cotton gloves prepares lightning, fires and earthquakes to the New York City elite!

**John Smith:** Readers love the humor of our paper. But you confuse me stating that your findings, which have immense benefits for the people, representing the game. Many will frown on it.

**Nikola Tesla:** Dear Mr. Smith, the trouble is that people are too serious. If they were not, they would be happier and much longer would have lived. Chinese proverb says that the seriousness reduces life. Visiting the inn Tai Pe guessed that he visits the Imperial Palace. But that the newspaper readers would not have frowned, let's get back to things which they consider important.

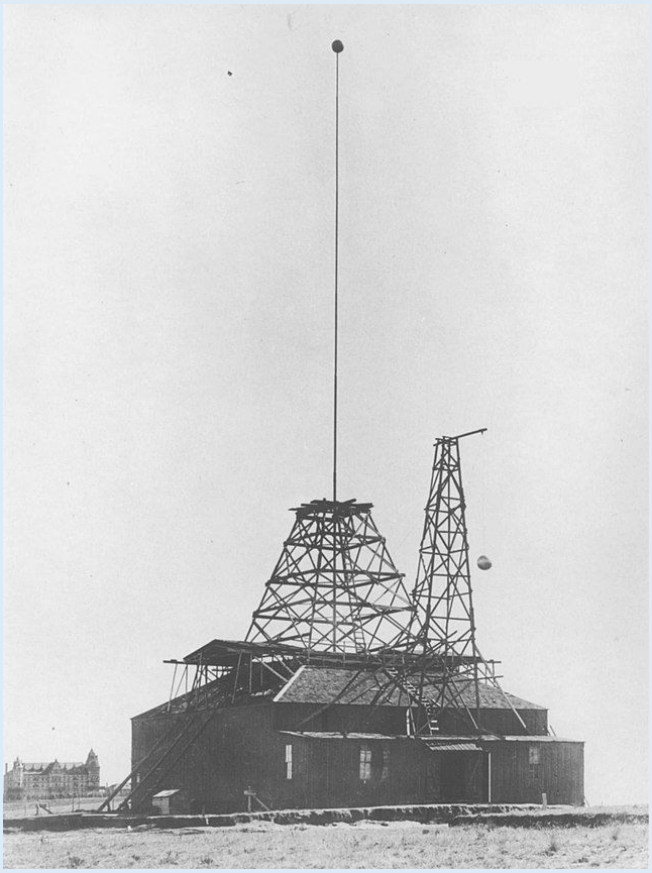
**John Smith:** They would love to hear what your philosophy is.

**Nikola Tesla:** Life is a rhythm that must be comprehended. I feel the rhythm and direct on it and pamper in it. It was very grateful and gave me the knowledge I have. Everything that lives is related to a deep and wonderful relationship: man and the stars, amoebas' and the sun, the heart and the circulation of an infinite number of worlds. These ties are unbreakable, but they can be tame and to propitiate and begin to create new and different relationships in the world, and that does not violate the old.

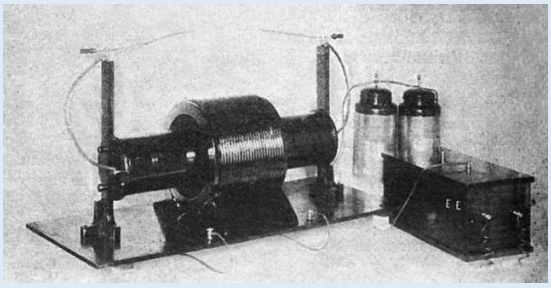
Knowledge comes from space; our vision is its most perfect set. We have two eyes: the earthly and spiritual. It is recommended that it become one eye. Universe is alive in all its manifestations, like a thinking animal.

Stone is a thinking and sentient being, such as plant, beast and a man. A star that shines asked to look at, and if we are not a sizeable self-absorbed we would understand its language and message. His breathing, his eyes and ears of the man must comply with breathing, eyes and ears of the Universe.

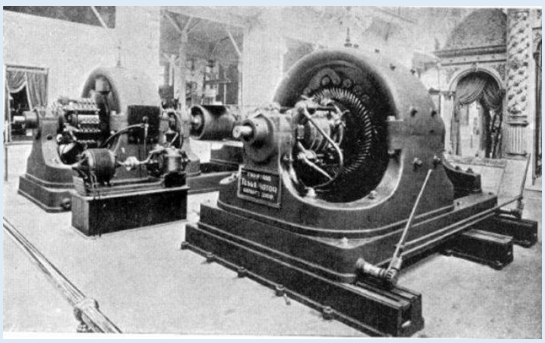
**John Smith:** As you say this, it seems to me like I hear Buddhist texts, words or Taoist Parazulzusa.



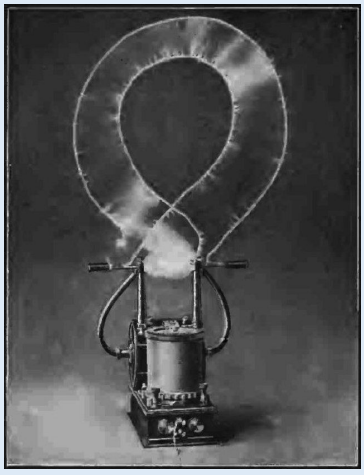
**Nikola Tesla's Colorado Springs laboratory**, where during the period 1899 – 1900 he conducted experiments in wireless power transmission.



A **Tesla coil**, a resonant transformer circuit invented by **Nikola Tesla** that generates very high voltage, radio frequency alternating current electricity at low current levels.

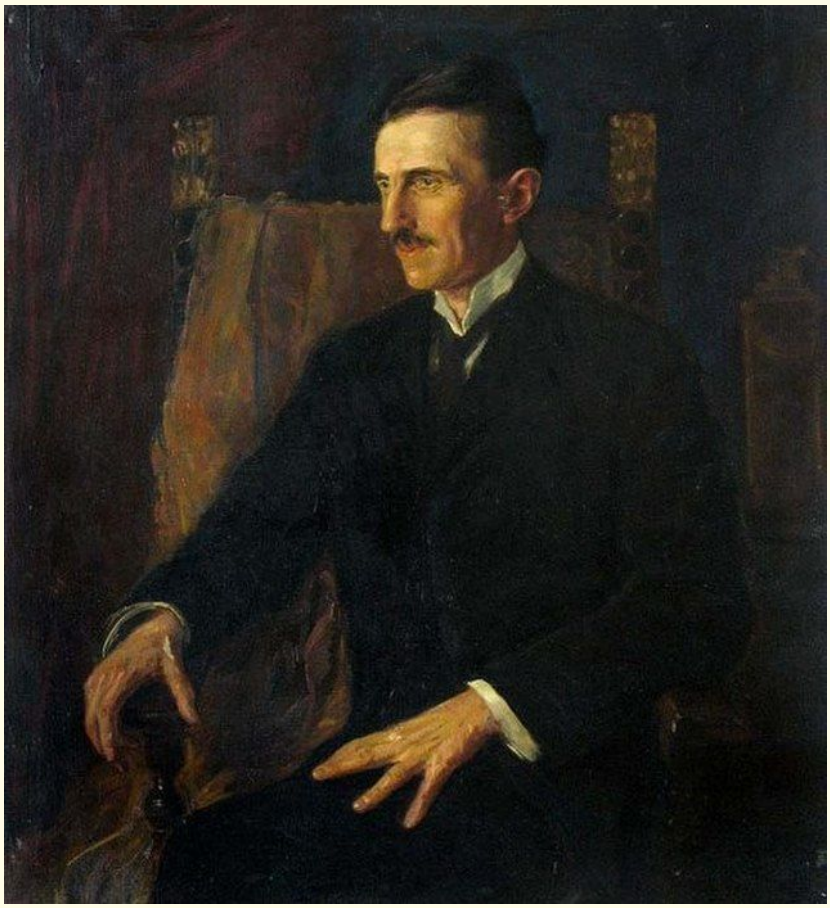


Nikola Tesla's Polyphase Alternating Current 500 horse power generator, in Westinghouse exhibit in the Electricity building of the 1893 World Columbian Exposition in Chicago.



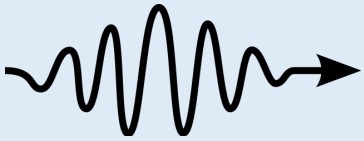
Small Tesla coil a resonant transformer circuit invented in 1891 by **Nikola Tesla** which produces high voltage, high frequency electricity. Owned by **William Thompson**, Lord Kelvin, who did some of the first mathematical analysis of resonance in electrical circuits.



**"If your hate could be turned into electricity,**

**it would light up the whole world."**



**– Nikola Tesla**

**Nikola Tesla:** That's right! This means that there is general knowledge and truth that man has always possessed. In my feeling and experience, the Universe has only one substance and one supreme energy with an infinite number of manifestations of life. The best thing is that the discovery of a secret nature, reveals the other.

One cannot hide, there are around us, but we are blind and deaf to them. If we emotionally tie ourselves to them, they come to us themselves. There are a lot of apples, but one Newton. He asked for just one apple that fell in front of him.

**John Smith:** A question that might be set at the beginning of this conversation. What was Electricity for you, Dear Mr. Tesla?

**Nikola Tesla:** Everything is Electricity. First was the light, endless source from which points out material and distribute it in all forms that represent the Universe and the Earth with all its aspects of life. Black is the true face of Light, only we do not see this. It is remarkable grace to man and other creatures. One of its particles possesses light, thermal, nuclear, radiation, chemical, mechanical and an unidentified energy.

It has the power to run the Earth with its orbit. It is true Archimedean lever.

**John Smith:** Mr. Tesla, you're too biased towards electricity.

**Nikola Tesla:** Electricity I am. Or, if you wish, I am the electricity in the human form. You are Electricity; too Mr. Smith, but you do not realize it.

**John Smith:** Is it thus your ability to allow fails of electricity of one million volts trough your body?

**Nikola Tesla:** Imagine a gardener who is attacked by herbs. This would indeed be crazy. Man's body and brain are made from a large amount energy; in me there is the majority of electricity. The energy that is different in everyone is what makes the human "I" or "soul". For other creatures to their essence, "soul" of the plant is the "soul" of minerals and animals.

Brain function and death is manifested in light. My eyes in youth were black, now blue, and as time goes on and strain the brain gets stronger, they are closer to white. White is the color of heaven. Through my window one morning, landed a white dove, which I fed. She wanted to bring me a word that she was dying. From her eyes the light jets were coming out. Never in the eyes of any creature had I not seen so much light, as in that pigeon.

**John Smith:** Personnel in your lab speak about flashes of light, flames and lightning that occur if you are angry or into kind of risk.

**Nikola Tesla:** It is the psychic discharge or a warning to be alert. The light was always on my side. Do you know how I discovered the rotating magnetic field and induction motor, which made me became famous when I was twenty-six? One summer evening in Budapest, I watched with my friend Sigetijem sunset.

Thousands of fire was turning around in thousands of flaming colors. I remembered Faust and recited his verses and then, as in a fog, I saw spinning magnetic field, and induction motor. I saw them in the sun!

**John Smith:** Hotel service telling that at the time of lightning you isolate into the room and talk to yourselves.

**Nikola Tesla:** I talk with lightning and thunder.

**John Smith:** With them? What language, Mr.Tesla?

**Nikola Tesla:** Mostly my native language. It has the words and sounds, especially in poetry, what is suitable for it.

**John Smith:** Readers of our magazine would be very grateful if you would interpret that.

**Nikola Tesla:** The sound does not exist only in the thunder and lightning, but, in transformation into the brightness and color. A color can be heard. Language is of the words, which means that it is from the sounds and colors. Every thunder and lightning are different and have their names. I call some of them by the names of those who were close in my life, or by those whom I admire.

In the sky brightness and thunder live my mother, sister, brother Daniel, a poet Jovan Jovanovic Zmaj and other persons of Serbian history. Names such AsIsaiah, Ezekiel, Leonardo, Beethoven, Goya, Faraday, Pushkin and all burning fires mark shoals and tangles of lightning and thunder, which does not stop all night bringing to the Earth precious rain and burning trees or villages.

There is lightning and thunder, and they are the brightest and most powerful, that will not vanish. They are coming back and I recognize them among the thousands.

**John Smith:** For you, science or poetry is the same?

**Nikola Tesla:** These are the two eyes of one person. William Blake was taught that the Universe was born from the imagination, that it maintains and it will exist as long as there is a last man on the Earth. With it was a wheel to which astronomers can collect the stars of all galaxies. It is the creative energy identical to the light energy.

**John Smith:** Imagination is more real to you than life itself?

**Nikola Tesla:** It gives birth to the life. I have fed by my taught; I've learned to control emotions, dreams and visions. I have always cherished, as I nurtured my enthusiasm. All my long life I spent in ecstasy. That was the source of my happiness. It helped me during all these years to bear with work, which was enough for the five lives. The best is to work at night, because the stellar light, and close bond.

**John Smith:** You said that I am, like every being, the Light. This flatter me, but I confess, I do not quite understand.

**Nikola Tesla:** Why would you need to understand, Mr. Smith? Suffice it to believe it. Everything is light. In one its ray is the fate of nations, each nation has its own ray in what great light source we see as the sun. And remember: no one who was there did not die. They transformed into the light, and as such exist still. The secret lies in the fact that the light particles restore their original state.

**John Smith:** This is the resurrection!

**Nikola Tesla:** I prefer to call it: return to a previous energy. Christ and several others knew the secret. I am searching how to preserve human energy. It is forms of Light, sometimes straight like heavenly light. I have not looked for it for my own sake, but for the good of all. I believe that my discoveries make people's lives easier and more bearable, and channel them to spirituality and morality.

**John Smith:** Do you think that time can be abolished?

**Nikola Tesla:** Not quite, because the first feature of the energy is that it transforms. It is in perpetual transformation, as clouds of Taoists. But it is possible to leverage the fact that a man preserves consciousness after the earthly life. In every corner of the universe exist energy of life; one of them is immortality, whose origin is outside of man, waiting for him.

The universe is spiritual; we are only half that way. The Universe is more moral than us, because we do not know his nature and how to harmonize our lives with it. I am not scientist, science is perhaps the most convenient way to find the answer to the question that always haunt me, and which my days and nights turned into fire.

**John Smith:** What's the matter?

**Nikola Tesla:** How are your eyes brightened!… What I wanted to know is: what happens to a falling star as the sun goes out? Stars fall like dust or seed in this or in other worlds, and the sun be scattered in our minds, in the lives of many beings, what will be reborn as a new light, or cosmic wind scattered in infinity.

I understand that this is necessary included in the structure of the Universe. The thing is, though, is that one of these stars and one of these suns, even the smallest, preserves.

**John Smith:** But, Mr. Tesla, you realize that this is necessary and is included in the constitution of the world!

**Nikola Tesla:** When a man becomes concuss; that his highest goal must be to run for a shooting star, and tries to capture it; shall understand that his life was given to him because of this and will be saved. Stars will eventually be capable to catch!

**John Smith:** And what will happen then?

**Nikola Tesla:** The creator will laugh and say: "It fall only that you chase her and grab her."

**John Smith:** Isn't all of this contrary to the cosmic pain, which so often you mention in your writings? And what is it cosmic pain?

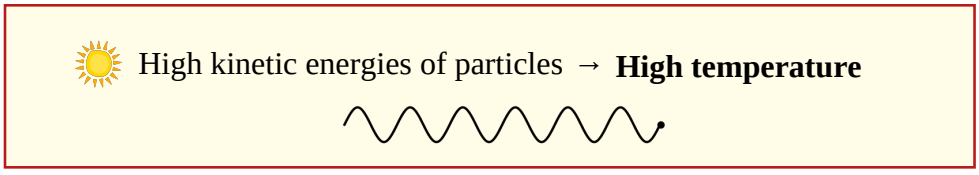
**Nikola Tesla:** No, because we are on Earth … It is an illness whose existence the vast majority of people are not aware of. Hence, many other illnesses, suffering, evil, misery, wars and everything else what makes human life an absurd and horrible condition. This disease cannot be completely cured, but awareness shall make it less complicated and hazardous. Whenever one of my close and dear people were hurt, I felt physical pain. This is because our bodies are made as of similar material, and our soul related with unbreakable strands. Incomprehensible

sadness that overwhelmed us at times means that somewhere, on the other side on this planet, a child or generous man died.

The entire Universe is in certain periods sick of itself, and of us. Disappearance of a star and the appearance of comets affect us more than we can imagine. Relationships among the creatures on the Earth are even stronger, because of our feelings and thoughts the flower will scent even more beautiful or will fall in silence.

These truths we must learn in order to be healed. Remedy is in our hearts and evenly, in the heart of the animals that we call the Universe.

The temperatures of the stars are very high and they radiate tremendous amount of energy. The hotter the stars, the greater their power output per unit surface area. The sun is one of the innumerable stars which radiate power at a rate $\propto$ fourth power of its effective surface temperature. The sun radiates $4.52 \times 10^{26}$ Joules of energy per second through its surface area. The origin of such a tremendous amount of energy is neither chemical nor gravitational. In 1939, German-American nuclear physicist **Hans Albrecht Bethe** suggested that source of stellar energy is nuclear fusion of two lighter nuclei to form a single heavier nucleus. But it is not easy to fuse the light nuclei into a single nucleus. The nuclei feel **strong nuclear force** only at very small distance scale ($\approx 1.2\sqrt[3]{A}$ fm). If speed is too small, strong interaction does not occur and fusion does not occur. Fusion is possible when the kinetic energy of the each of the nuclei is large enough to overcome the Coulomb potential ($\approx 0.15\ A^{\frac{5}{3}}$). With $A \approx 8$ we have Coulomb potential $\approx 4.8$ MeV.




Hence, fusion reactions can take place only at very high temperature of the order of $10^7$ to $10^9$ Kelvin. Hence, reactions are termed **thermonuclear reactions**.

A star is able to control **thermonuclear fusion** in its core because of its strong self gravity. The thermonuclear reactions in the core of the star cause high temperature which generates strong outward pressure – this act against the **star's own gravity** preventing it from contracting and holding it in equilibrium.

In ordinary stars, nuclear fusion takes place through **proton-proton cycle** or **carbon-nitrogen-oxygen cycle** depending on the mass of the star. The **proton-proton cycle** occurs in less massive stars with smaller central temperature ($\approx 10^7$ Kelvin). In sun and other low mass on the main sequence, 90% of the energy produced because of **proton-proton cycle**. In more massive stars in which temperature exceeds $15 \times 10^6$ Kelvin, hydrogen burning can occur with an entirely different sequence of reactions in which $_6C^{12}$ **nucleus** acts as a catalyst. In this process, reactions proceed with the formation of nitrogen and oxygen isotopes. The entire cycle is called **CNO cycle**.

4 protons → 1 helium nucleus + 2 positrons + KE

Irrespective of pp or CNO cycle

Total energy released in the form of kinetic energy of different particles.

**Plasma is the most abundant state of matter in the universe, making up more than 99% of all known matter. This is because plasma is found in stars, the solar wind, and even in the Earth's atmosphere.**

| |
|---|
| 65 % Oxygen |
| 18.5 % Carbon |
| 9.5 % Hydrogen |
| 3.2 % Nitrogen |
| 1.5 % Calcium |
| 1 % Phosphorus |
| 0.4 % Potassium |
| 0.3 % Sulphur |
| 0.2 % Sodium |
| 0.4 % Cl, Mg, Mn, Fe, F, Co, Cu, Zn, Se, Mo, I, Li, Al |

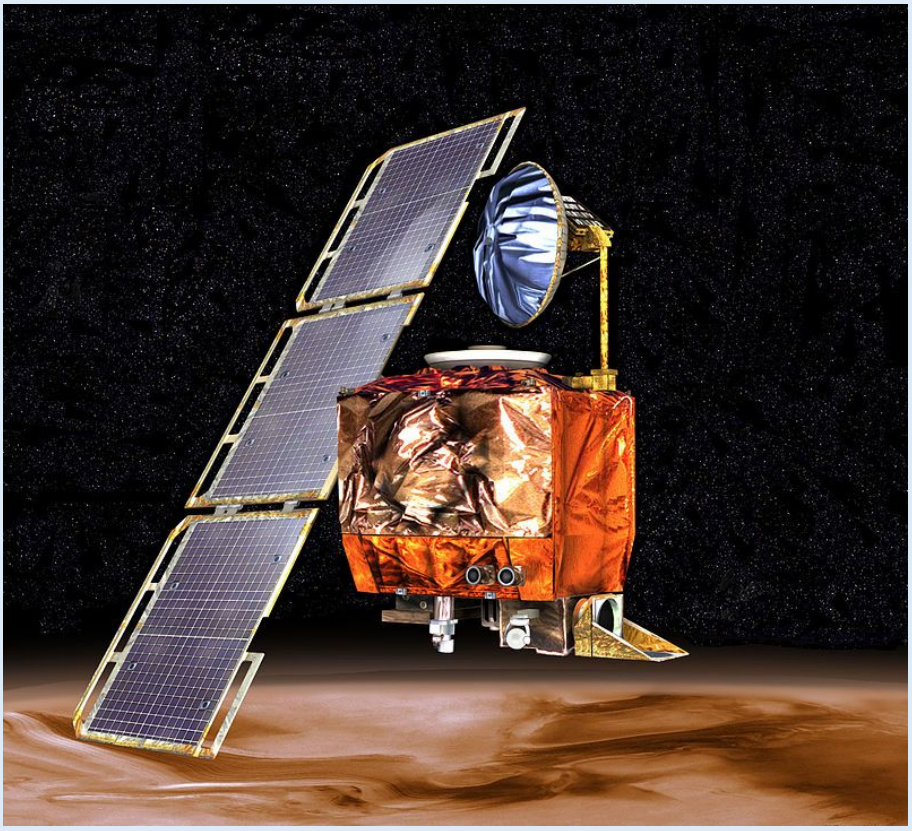
Nearly all the elements in the human body were made in a star and many have come through several supernovas.

## Fringe science

Investigations within an established field of study that deviate significantly from mainstream theories in that domain and are generally regarded as questionable by the mainstream community.

## Planet Simulator

Also referred to as a **Planetary Simulator**, is a machine designed to study the origin of life on Earth and potentially on other planets in the cosmos.



Artistic rendering of the **Mars Climate Orbiter**, a robotic space probe launched by NASA on December 11, 1998, with the primary purpose of studying the climate, atmosphere, and surface variations on Mars.

## Taphonomy

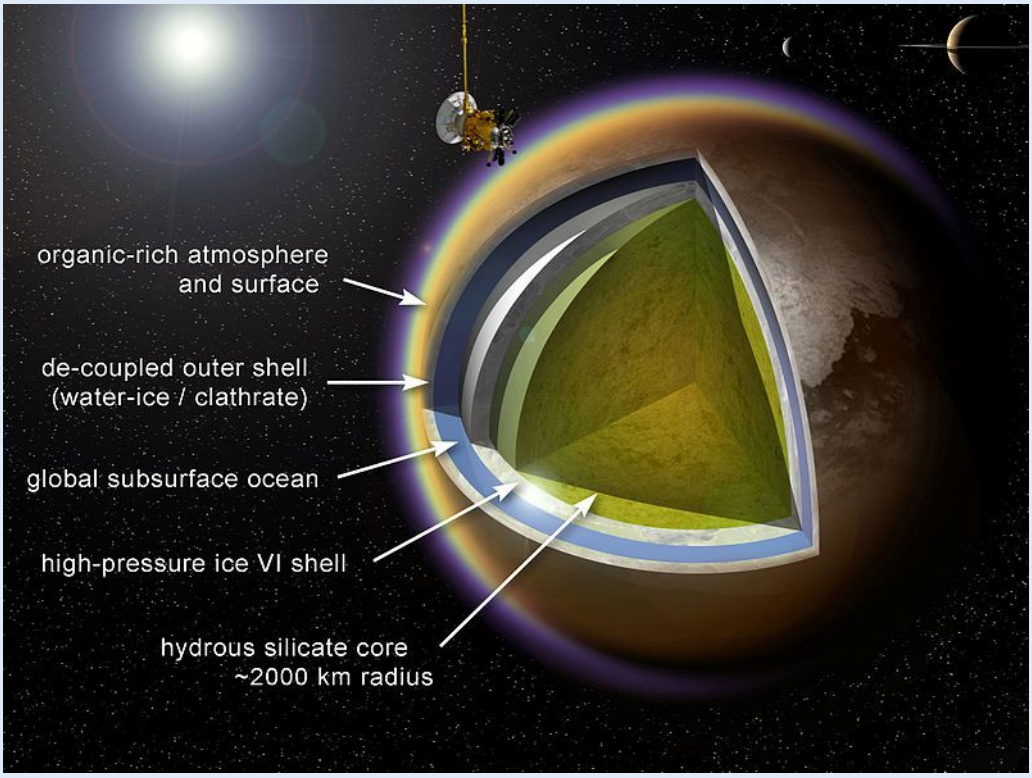
The scientific investigation of the processes involved in the decomposition, fossilization, and preservation of organisms within the paleontological record.



The iconic "Earthrise" image was captured by astronaut **William Anders** on December 24, 1968, during the **Apollo 8 mission**. It shows the Earth rising above the lunar horizon as seen from the spacecraft while orbiting the Moon.

## Hypothetical types of biochemistry

Theoretical forms of biochemical systems that are considered scientifically conceivable but have not been confirmed or observed in the natural world. These hypothetical types of biochemistry are often explored to expand our understanding of the possible diversity of life and the fundamental principles that govern living systems.




An artist's concept illustrates a plausible model of **Titan's internal structure**, utilizing data gathered from **NASA's Cassini spacecraft**. The model delves into the inner layers of **Saturn's largest moon**, providing insights into its composition and structure.

## ✓ Space propaganda

A type of propaganda that focuses on showcasing achievements in space exploration and space science.




✓ **Postage Stamp depicting Neil Armstrong's first steps on the moon**

## Thorne–Żytkow object

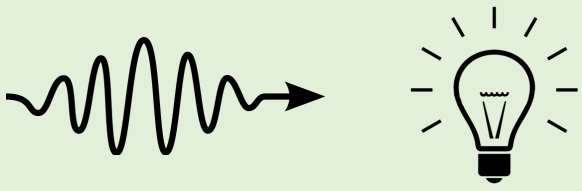
A **"hybrid star,"** also referred to as a **"hybrid celestial object,"** is a theoretical concept suggesting the presence of a neutron star at the core of a red giant or red supergiant star. This intriguing scenario is proposed to arise from a collision between the red giant and a neutron star.

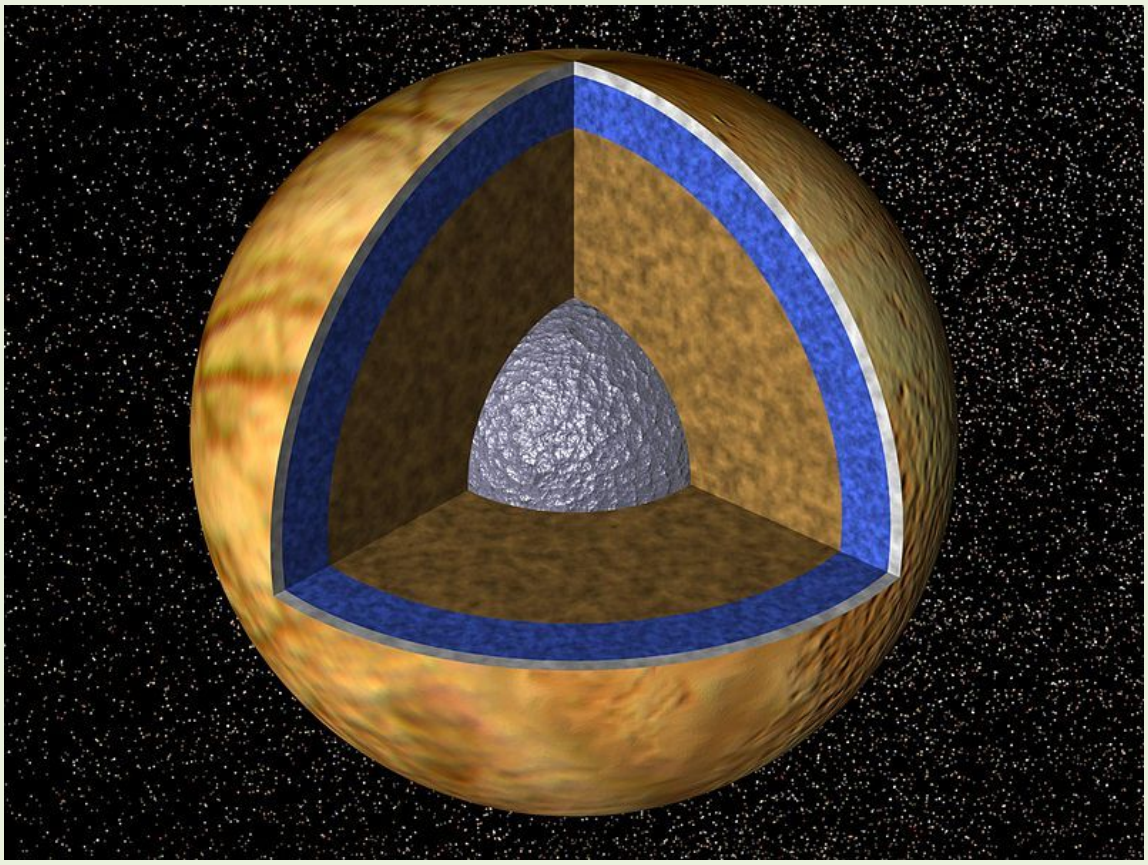
## Blitzars

A theoretical category of **neutron stars**, particularly **pulsars**, which possess the potential to undergo rapid transformation into **black holes** if their spinning slows down. These celestial entities were introduced as a concept by **Heino Falcke** and **Luciano Rezzolla** in 2013. The proposal was put forth in an attempt to provide an explanation for the phenomenon known as **fast radio bursts** (FRBs).

## Planet V

A theoretical fifth terrestrial planet proposed by **NASA** scientists **John Chambers and Jack J. Lissauer** to have once occupied the space between Mars and the asteroid belt.





## The interior of Europa

**Europa** is one of Jupiter's largest moons, and it's believed to have a subsurface ocean of liquid water beneath its icy crust. The **interior of Europa** is thought to consist of three main layers: **an outer icy crust, a subsurface ocean, and a rocky mantle**. The **icy crust of Europa** is estimated to be around 10−30 kilometers thick, and is thought to be composed primarily of water ice, along with small amounts of other materials. Beneath the crust lies the **subsurface ocean**, which is believed to have a depth of up to 100 kilometers and is thought to contain more than twice the amount of water found on **Earth**. The ocean is thought to be kept in a liquid state by tidal heating, caused by the gravitational forces of Jupiter and other nearby moons. The **rocky mantle of Europa** is believed to lie beneath the subsurface ocean and is thought to be similar in composition to the mantles of **Earth and other terrestrial planets**. However, the exact nature and properties of **Europa's mantle** are still largely unknown, and further exploration and study of the moon will be necessary to gain a better understanding of its interior structure and composition.

## Astrophilately

A specialized field within **philately** that focuses on the collection and study of postage stamps and postmarked envelopes that are related to **spaceflight** and **space exploration**.

## Ultra-high-energy cosmic ray

A **cosmic ray** possessing an energy greater than **1 EeV** ($10^{18}$ electronvolts, roughly equivalent to 0.16 joules)

## Star party

A gathering of **amateur astronomers** who come together with the intention of observing celestial objects and phenomena in the night sky.



**A star party in California** entails an event where amateur astronomers gather to collectively observe and appreciate celestial objects and occurrences in the night sky within the state of California.

## Plasma-filled cosmos

According to this theory, the **universe** was initially hot, dense **plasma**, and as it expanded and cooled, the **plasma** gradually recombined into neutral atoms, forming the first stars and galaxies. The universe was then reionized by the **radiation** from the **first generation of stars**, and has remained partially ionized ever since.

## Superfluid space-time

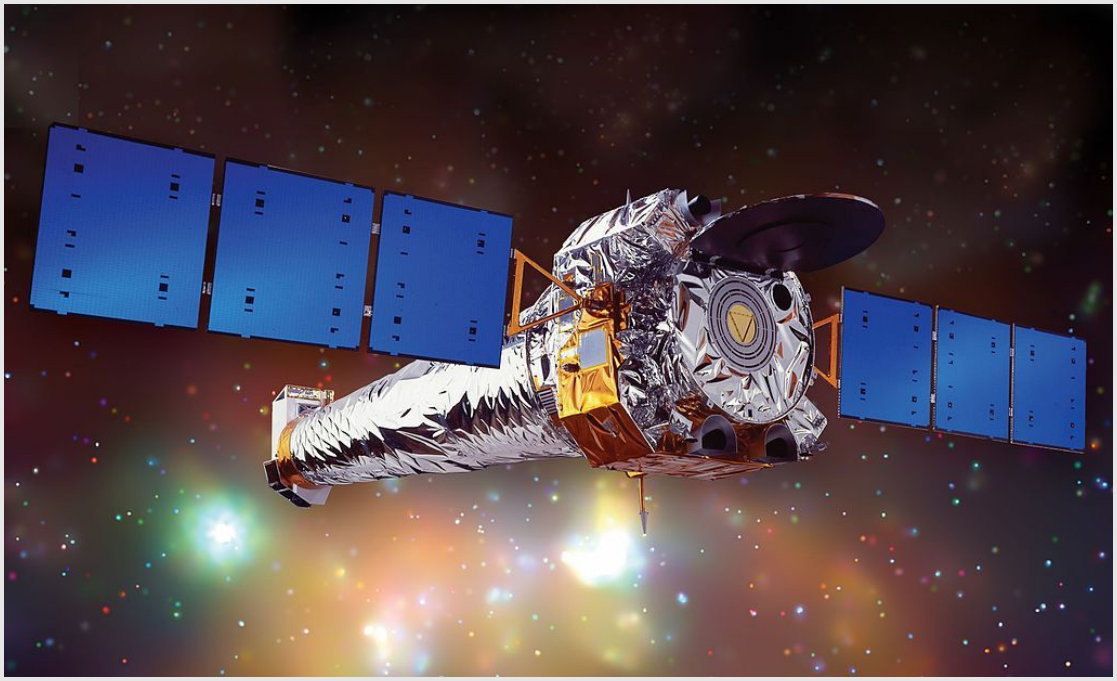
The idea that **space-time** itself may possess properties similar to those of a **superfluid**, a type of fluid with zero viscosity that is characterized by its ability to flow without resistance. In a **superfluid space-time**, the fabric of **space-time** itself is thought to be able to flow and change its shape in a similar way to a **superfluid**. This idea has been proposed as a way to explain certain phenomena in physics, such as the **behaviour of cosmic strings** and the **formation of structure in the universe**.

## Mars Micro Orbiter

A **spacecraft mission concept** aimed at deploying a small and inexpensive satellite into orbit around Mars. Its primary objective is to investigate some aspects of the **Mars atmosphere** in visible and infrared wavelengths.

## High-energy astronomy

A **branch of astronomy** that focuses on the study of celestial objects and phenomena that emit or interact with **high-energy radiation**, such as **X-rays** and **gamma rays**. This field of **astronomy** provides valuable insights into the extreme conditions and processes occurring in the universe, including **powerful cosmic events** and **exotic astrophysical objects**.



Artistic depiction of the **Chandra X-ray Observatory**, a prominent space telescope designed to detect and capture high-energy **X-ray emissions** from various celestial sources.

## Robotic telescope

An astronomical instrument consisting of a telescope and a detection system that conducts observations autonomously, without the need for human intervention.

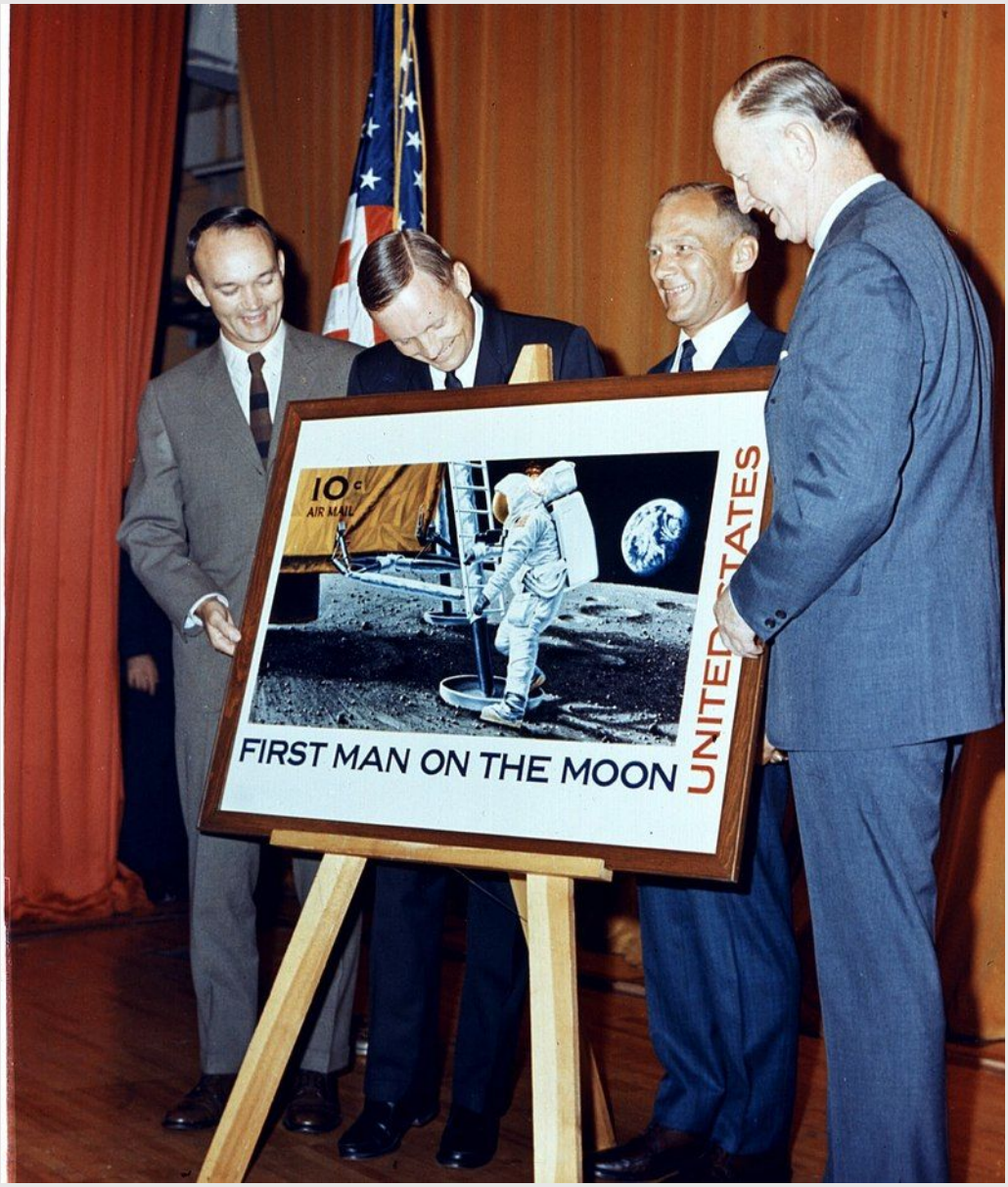
## Space diving

The act of jumping from an **aircraft** or **spacecraft** positioned in the near space and falling towards Earth through **free-fall**.



At an altitude of 102,800 feet (31,300 meters) on August 16, 1960, **Joseph Kittinger**, an officer in the **United States Air Force** (USAF) who served from 1950 to 1978, took the momentous step from the balloon-supported Excelsior gondola.

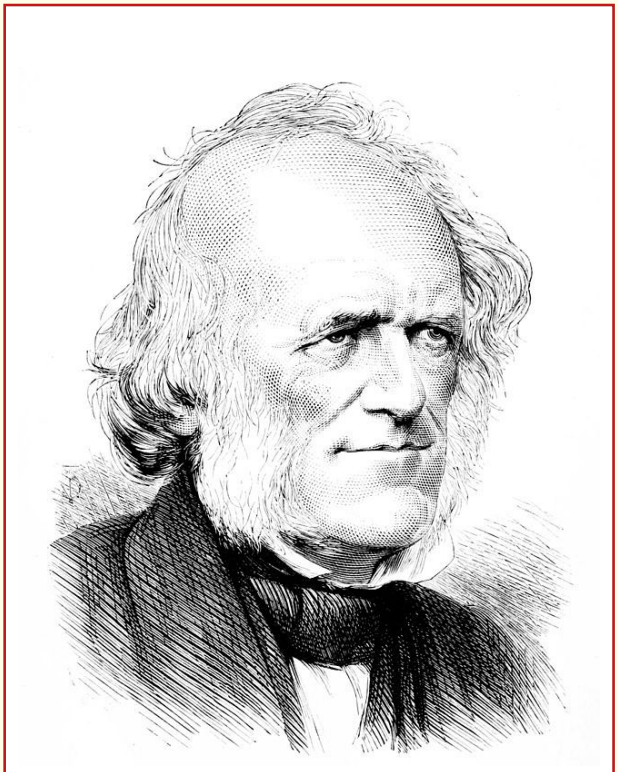



**Apollo 11 astronauts** unveiling **First Man on the Moon** stamp with U.S. Postmaster General **Winton M. Blount**







✓ **Charles Lyell**

**Charles Darwin's letter to Charles Lyell [18 June 1858]**

**My dear Lyell**

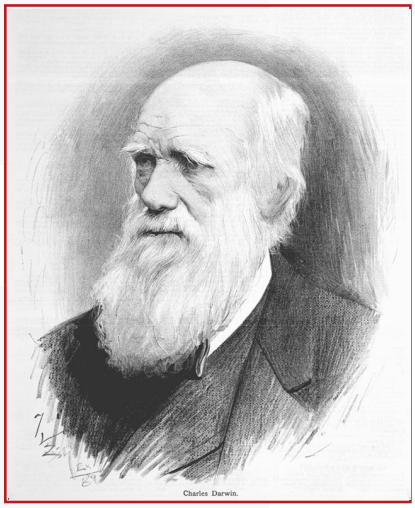
Some year or so ago, you recommended me to read a paper by Wallace in the Annals, which had interested you & as I was writing to him, I knew this would please him much, so I told him. He has today sent me the enclosed & asked me to forward it to you. It seems to me well worth reading. Your words have come true with a vengeance that I should be forestalled. You said this when I explained to you here very briefly my views of "Natural Selection" depending on the Struggle for existence. I never saw a more

striking coincidence. If Wallace had my M.S. sketch written out in 1842 he could not have made a better short abstract! Even his terms now stand as Heads of my Chapters.

Please return me the M.S. which he does not say he wishes me to publish; but I shall of course at once write & offer to send to any Journal. So all my originality, whatever it may amount to, will be smashed. Though my Book, if it will ever have any value, will not be deteriorated; as all the labour consists in the application of the theory.

I hope you will approve of Wallace's sketch, that I may tell him what you say.

**My dear Lyell | Yours most truly | C. Darwin**




**Charles Darwin's letter to Charles Lyell [25 June 1858]**

**My dear Lyell**

I am very very sorry to trouble you, busy as you are, in so merely personal an affair. But if you will give me your deliberate opinion, you will do me as great a service, as ever man did, for I have entire confidence in your judgment & honour.

I should not have sent off your letter without further reflexion, for I am at present quite upset, but write now to get subject for time out of mind. But I confess it never did occur to me, as it ought, that Wallace could have made any use of your letter.

There is nothing in Wallace’s sketch which is not written out much fuller in my sketch copied in 1844, & read by Hooker some dozen years ago. About a year ago I sent a short sketch of which I have copy of my views (owing to correspondence on several points) to Asa Gray, so that I could most truly say & prove that I take nothing from Wallace. I should be extremely glad now to publish a sketch of my general views in about a dozen

pages or so. But I cannot persuade myself that I can do so honourably. Wallace says nothing about publication, & I enclose his letter. But as I had not intended to publish any sketch, can I do so honourably because Wallace has sent me an outline of his doctrine? I would far rather burn my whole book than that he or any man should think that I had behaved in a paltry spirit. Do you not think his having sent me this sketch ties my hands? I do not in least believe that that he originated his views from anything which I wrote to him.

If I could honourably publish I would state that I was induced now to publish a sketch (& I should be very glad to be permitted to say to follow your advice long ago given) from Wallace having sent me an outline of my general conclusions. We differ only, that I was led to my views from what artificial selection has done for domestic animals. I could send Wallace a copy of my letter to Asa Gray to show him that I had not stolen his doctrine. But I cannot tell whether to publish now would not be base & paltry: this was my first impression, & I should have certainly acted on it, had it not been for your letter.

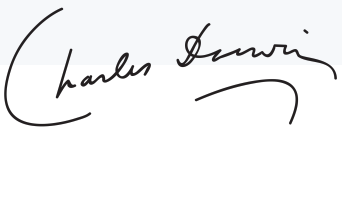
This is a trumpery affair to trouble you with; but you cannot tell how much obliged I should be for your advice.

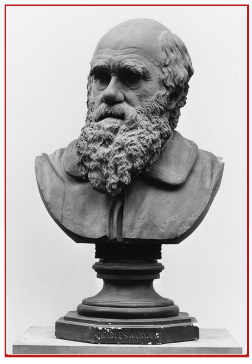
By the way would you object to send this & your answer to Hooker to be forwarded to me, for then I shall have the opinion of my two best & kindest friends. This letter is miserably written & I write it now, that I may for time banish whole subject. And I am worn out with musing.

I fear we have case of scarlet-fever in House with Baby. Etty is weak but is recovering.

My good dear friend forgive me. This is a trumpery letter influenced by trumpery feelings.

**Yours most truly | C. Darwin**





I will never trouble you or Hooker on this subject again



**Bertrand Russell's Artful Letter Stating His Refusal to Debate British Fascist Leader Oswald Mosley (1962)**



**Dear Sir Oswald,**

Thank you for your letter and for your enclosures. I have given some thought to our recent correspondence. It is always difficult to decide on how to respond to people whose ethos is so alien and, in fact, repellent to one's own. It is not that I take exception to the general points made by you but that every ounce of my energy has been devoted to an active opposition to cruel bigotry, compulsive violence, and the sadistic persecution which has characterized the philosophy and practice of fascism.

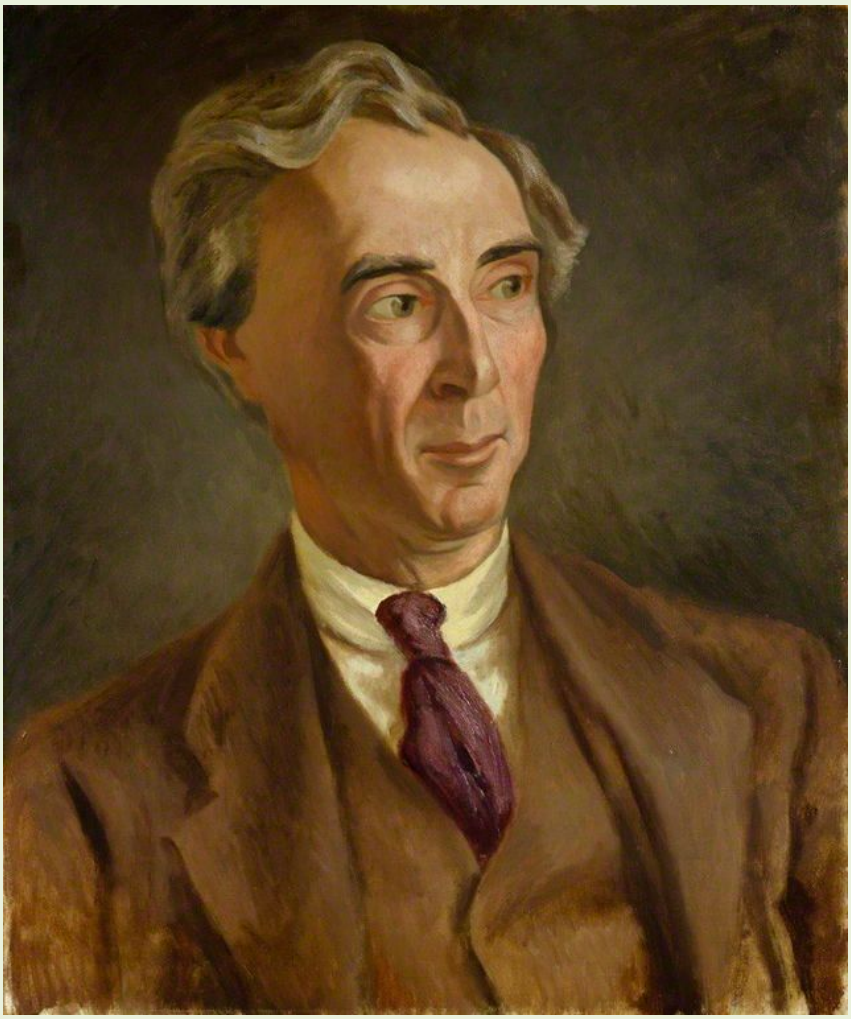
I feel obliged to say that the emotional universes we inhabit are so distinct, and in deepest ways opposed, that nothing fruitful or sincere could ever emerge from association between us.

I should like you to understand the intensity of this conviction on my part. It is not out of any attempt to be rude that I say this but because of all that I value in human experience and human achievement.

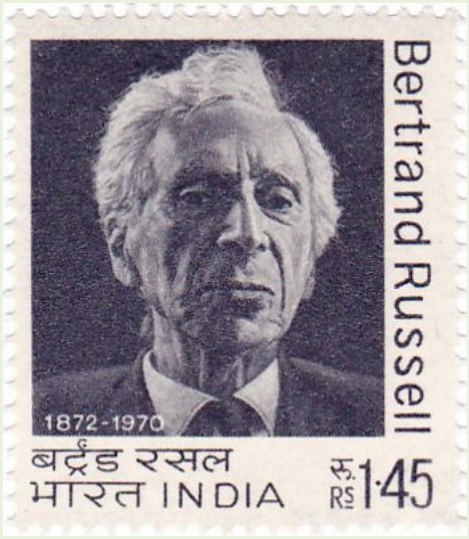
**Yours sincerely,**



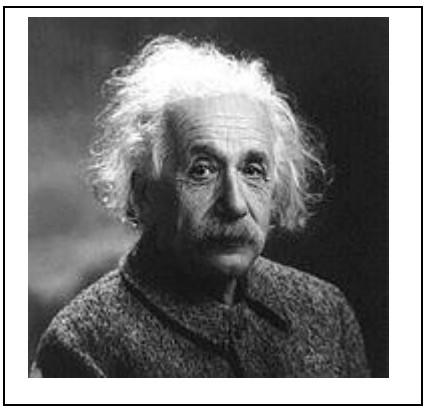
**Bertrand Russell**



Bertrand Russell



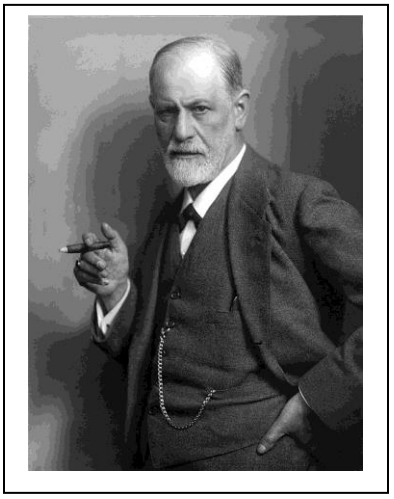

**Russell on a 1972 stamp of India**





Einstein in 1893 (age 14)





Sigm. Freud

Freud (aged 16) and his mother, Amalia, in 1872

| | |
|---|---|
| **Oort Cloud** | Cloud of comets and minor planets that are inferred to revolve around the Sun at distances ranging from 0.03 to 3.2 light-years |
| **Planck length**<br>$\sqrt{\frac{\hbar G}{c^3}}$ | The length scale below which space as we know it ceases to exist and becomes<br>The quantum fluctuation of spacetime on very small scales due to quantum mechanics<br>**quantum foam**<br>**Fireball**<br>An extremely bright meteor |
| **Thorne-Żytkow objects** | Giant stars that have a neutron star core with an extended hydrogen-rich envelope |
| | |
| **Apastron** | The point of maximum separation between the two stars in a **binary star system**<br>A system of 2 stars that revolve around a common center of gravity |
| **Christian Doppler**<br>19th century Austrian physicist who discovered the variation in the wavelength of waves caused by motion of the wave source. | **One bar = 0.987 atmospheres**<br>**Double Asteroid:** 2 asteroids that revolve around each other and are held together by the gravity between them |
| **Steady State Theory** | Matter must be continually created to maintain the constant density of the universe. Numerous observations have discredited the theory. |
| **NBODY** | Code to carry out N-body simulations for stellar dynamics − developed by a research scientist at the Institute of Astronomy at the University of Cambridge (**Sverre Johannes Aarseth**) |
| **Cosmogony:** The study of celestial systems including the Solar System, stars, galaxies and galactic clusters.<br>**Cosmology:** A branch of science that deals with the study of the origin, structure and nature of the universe. | |
| **Extragalactic** | Outside or beyond our own galaxy<br>**Extraterrestrial:** from outside the earth or its atmosphere |
| **Abell Catalog** | Catalogue of Rich Clusters of Galaxies assembled over 1950s-1980s |

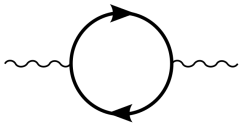
**Greenhouse Effect**

An increase in temperature caused when gases in Earth's atmosphere trap the Sun's heat

**The heavy isotope of hydrogen (deuterium) was discovered by Harold Clayton Urey and his coworkers in 1931 by spectrographic methods. This however was predicted by Ernest Rutherford in 1920.**

## ✓ Rutherford model:

- All the mass and the positive charge in an atom is concentrated in a tiny nucleus of radius of the order of a few fermi (1 fm = $10^{-15}$m)
- Negatively charged electrons reside outside the nucleus



Used up in doing work against the forces which bind the nucleons together

When **deuterium** is bombarded by a **2.223 MeV** gamma ray photon, it breaks up into a proton and a neutron

When **deuterium** is bombarded by a gamma ray photon of energy > **2.223 MeV**, the extra energy goes to provide kinetic energy to liberated nucleons.

The more tightly bound a nucleus is, the stronger the nuclear forces that hold it together and the greater the binding energy **($BE = \Delta mc^2$)** required to pull it apart.

| | |
|---|---|
| **Yukawa's theory** | A fundamental theory of nuclear forces involving the exchange of massive charged particles (**having a mass about 200 times that of an electron**) between neutrons and protons. |
| **Galilean Moons** | The 4 largest moons of Jupiter:<br>• Io<br>• Europa<br>• Ganymede<br>• Callisto |

First observed by Italian astronomer **Galileo Galilei** in December 1609 or January 1610, and recognized by him as satellites of Jupiter in March 1610.

**Hypergalaxy**

A system that consists of a dominant spiral galaxy that is surrounded by a cloud of smaller satellite galaxies which are often elliptical

# ✓ Inferior Planet

A planet that orbits between the Earth and the Sun. Mercury and Venus are the only two inferior planets in our solar system.

| | |
|---|---|
| **Interplanetary Magnetic Field** | The magnetic field carried along with the solar wind |
| **Interstellar Medium** | The gas and dust that exist in the space between the star systems in a galaxy |
| **Iron Meteorite** | A meteorite that is composed mainly of iron mixed with smaller amounts of nickel |

**1 Kiloparsec = 1000 parsecs**

**Karl Guthe Jansky** was an American physicist and radio engineer who in August 1931 first discovered radio waves emitted from the Milky Way. He is considered one of the founding figures of radio astronomy.

**A lunar month is equal to 29 days 12 hours 44 minutes**

**Meteor Shower**

**An event where a large number of Meteors enter the Earth's atmosphere from one point in space at nearly the same time**

**Meteors** become **meteorites** if they reach the Earth's surface.

**Open clusters**

- Loosely bound groups of a few tens to a few hundred stars
- Found in spiral and irregular galaxies

**Planemo:** A large planet or planetary body that does not orbit a star.

## A letter from Albert Einstein to Sigmund Freud

**Dear Professor Freud,...**

Is there any way of delivering mankind from the menace of war?

It is common knowledge that, with the advance of modern science, this issue has come to mean a matter of life and death for civilization as we know it; nevertheless, for all the zeal displayed, every attempt at its solution has ended in a lamentable breakdown.

I believe, moreover, that those whose duty it is to tackle the problem professionally and practically are growing only too aware of their impotence to deal with it, and have now a very lively desire to learn the views of men who, absorbed in the pursuit of science, can see world-problems in the perspective distance lends. As for me, the normal objective of my thought affords no insight into the dark places of human will and feeling. Thus, in the enquiry now proposed, I can do little more than seek to clarify the question at issue and, clearing the ground of the more obvious solutions, enable you to bring the light of your far-reaching knowledge of man's instinctive life to bear upon the problem...

...As one immune from nationalist bias, I personally see a simple way of dealing with the superficial (i.e. administrative) aspect of the problem: the setting up, by international consent, of a legislative and judicial body to settle every conflict arising between nations. Each nation would undertake to abide by the orders issued by this legislative body, to invoke its decision in every dispute, to accept its judgments unreservedly and to carry out every measure the tribunal deems necessary for the execution of its decrees. But here, at the outset, I come up against a difficulty; a tribunal is a human institution which, in proportion as the power at its disposal is inadequate to enforce its verdicts, is all the more prone to suffer these to be deflected by extrajudicial pressure. This is a fact with which we have to reckon; law and might inevitably go hand in hand, and juridical decisions approach more nearly the ideal justice demanded by the community (in whose name and interests these verdicts are pronounced) in so far as the community has effective power to

compel respect of its juridical ideal. But at present we are far from possessing any supranational organization competent to render verdicts of incontestable authority and enforce absolute submission to the execution of its verdicts. Thus I am led to my first axiom: the quest of international security involves the unconditional surrender by every nation, in a certain measure, of its liberty of action, its sovereignty that is to say, and it is clear beyond all doubt that no other road can lead to such security.

The ill-success, despite their obvious sincerity, of all the efforts made during the last decade to reach this goal leaves us no room to doubt that strong psychological factors are at work, which paralyse these efforts. Some of these factors are not far to seek. The craving for power which characterizes the governing class in every nation is hostile to any limitation of the national sovereignty. This political power-hunger is wont to batten on the activities of another group, whose aspirations are on purely mercenary, economic lines. I have specially in mind that small but determined group, active in every nation, composed of individuals who, indifferent to social considerations and restraints, regard warfare, the manufacture and sale of arms, simply as an occasion to advance their personal interests and enlarge their personal authority.

But recognition of this obvious fact is merely the first step towards an appreciation of the actual state of affairs. Another question follows hard upon it: how is it possible for this small clique to bend the will of the majority, who stand to lose and suffer by a state of war, to the service of their ambitions? (In speaking of the majority, I do not exclude soldiers of every rank who have chosen war as their profession, in the belief that they are serving to defend the highest interests of their race, and that attack is often the best method of defence.) An obvious answer to this question would seem to be that the minority, the ruling class at present, has the schools and press, usually the Church as well, under its thumb. This enables it to organize and sway the emotions of the masses, and make its tool of them.

Yet even this answer does not provide a complete solution. Another question arises from it: How is it these devices succeed so well in rousing men to such wild enthusiasm, even

to sacrifice their lives? Only one answer is possible. Because man has within him a lust for hatred and destruction. In normal times this passion exists in a latent state, it emerges only in unusual circumstances; but it is a comparatively easy task to call it into play and raise it to the power of a collective psychosis. Here lies, perhaps, the crux of all the complex of factors we are considering, an enigma that only the expert in the lore of human instincts can resolve.

And so we come to our last question. Is it possible to control man's mental evolution so as to make him proof against the psychoses of hate and destructiveness? Here I am thinking by no means only of the so-called uncultured masses. Experience proves that it is rather the so-called "**Intelligentzia**" that is most apt to yield to these disastrous collective suggestions, since the intellectual has no direct contact with life in the raw, but encounters it in its easiest, synthetic form upon the printed page.

To conclude: I have so far been speaking only of wars between nations; what are known as international conflicts. But I am well aware that the aggressive instinct operates under other forms and in other circumstances. (I am thinking of civil wars, for instance, due in earlier days to religious zeal, but nowadays to social factors; or, again, the persecution of racial minorities). But my insistence on what is the most typical, most cruel and extravagant form of conflict between man and man was deliberate, for here we have the best occasion of discovering ways and means to render all armed conflicts impossible.

**Yours very sincerely,**



**A. Einstein**

**Richard Feynman's Letter to His Departed Wife**

**October 17, 1946**



**D’Arline,**

I adore you, sweetheart.

I know how much you like to hear that — but I don't only write it because you like it — I write it because it makes me warm all over inside to write it to you.

It is such a terribly long time since I last wrote to you — almost two years but I know you'll excuse me because you understand how I am, stubborn and realistic; and I thought there was no sense to writing.

But now I know my darling wife that it is right to do what I have delayed in doing, and that I have done so much in the past. I want to tell you I love you. I want to love you. I always will love you.

I find it hard to understand in my mind what it means to love you after you are dead — but I still want to comfort and take care of you — and I want you to love me and care for me. I want to have problems to discuss with you — I want to do little projects with you. I never thought until just now that we can do that. What should we do. We started to learn to make clothes together — or learn Chinese — or getting a movie projector. Can't I do something now? No. I am alone without you and you were the "idea-woman" and general instigator of all our wild adventures.

When you were sick you worried because you could not give me something that you wanted to and thought I needed. You needn’t have worried. Just as I told you then there was no real need because I loved you in so many ways so much. And now it is clearly even more true — you can give me nothing now yet I love you so that you stand in my

way of loving anyone else — but I want you to stand there. You, dead, are so much better than anyone else alive.

I know you will assure me that I am foolish and that you want me to have full happiness and don't want to be in my way. I'll bet you are surprised that I don't even have a girlfriend (except you, sweetheart) after two years. But you can't help it, darling, nor can I — I don't understand it, for I have met many girls and very nice ones and I don't want to remain alone — but in two or three meetings they all seem ashes. You only are left to me. You are real.

**My darling wife, I do adore you.**

**I love my wife. My wife is dead.**



**Rich.**

**PS Please excuse my not mailing this — but I don't know your new address.**

**Richard Feynman's Letter to his former student Koichi Manom**

**Dear Koichi,**

I was very happy to hear from you, and that you have such a position in the Research Laboratories. Unfortunately your letter made me unhappy for you seem to be truly sad. It seems that the influence of your teacher has been to give you a false idea of what are worthwhile problems. The worthwhile problems are the ones you can really solve or help solve, the ones you can really contribute something to. A problem is grand in science if it lies before us unsolved and we see some way for us to make some headway into it. I would advise you to take even simpler, or as you say, humbler, problems until you find some you can really solve easily, no matter how trivial. You will get the pleasure of

success, and of helping your fellow man, even if it is only to answer a question in the mind of a colleague less able than you. You must not take away from yourself these pleasures because you have some erroneous idea of what is worthwhile.

You met me at the peak of my career when I seemed to you to be concerned with problems close to the gods. But at the same time I had another Ph.D. Student (Albert Hibbs) whose thesis was on how it is that the winds build up waves blowing over water in the sea. I accepted him as a student because he came to me with the problem he wanted to solve. With you I made a mistake, I gave you the problem instead of letting you find your own; and left you with a wrong idea of what is interesting or pleasant or important to work on (namely those problems you see you may do something about). I am sorry, excuse me. I hope by this letter to correct it a little.

I have worked on innumerable problems that you would call humble, but which I enjoyed and felt very good about because I sometimes could partially succeed. For example, experiments on the coefficient of friction on highly polished surfaces, to try to learn something about how friction worked (failure). Or, how elastic properties of crystals depend on the forces between the atoms in them, or how to make electroplated metal stick to plastic objects (like radio knobs). Or, how neutrons diffuse out of Uranium. Or, the reflection of electromagnetic waves from films coating glass. The development of shock waves in explosions. The design of a neutron counter. Why some elements capture electrons from the L-orbits, but not the K-orbits. General theory of how to fold paper to make a certain type of child's toy (called flexagons). The energy levels in the light nuclei. The theory of turbulence (I have spent several years on it without success). Plus all the "grander" problems of quantum theory.

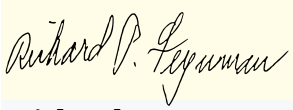
No problem is too small or too trivial if we can really do something about it.

You say you are a nameless man. You are not to your wife and to your child. You will not long remain so to your immediate colleagues if you can answer their simple questions when they come into your office. You are not nameless to me. Do not remain nameless to

yourself – it is too sad a way to be. Know your place in the world and evaluate yourself fairly, not in terms of your naïve ideals of your own youth, nor in terms of what you erroneously imagine your teacher's ideals are.

**Best of luck and happiness.**

**Sincerely,**



**Richard P. Feynman.**



## ✓ Einstein's Letter to His Son Hans Albert

**My dear Albert,**

Yesterday I received your dear letter and was very happy with it.

I was already afraid you wouldn't write to me at all anymore. You told me when I was in Zurich, that it is awkward for you when I come to Zurich. Therefore I think it is better if we get together in a different place, where nobody will interfere with our comfort.

I will in any case urge that each year we spend a whole month together, so that you see that you have a father who is fond of you and who loves you. You can also learn many good and beautiful things from me, something another cannot as easily offer you.

What I have achieved through such a lot of strenuous work shall not only be there for strangers but especially for my own boys. These days I have completed one of the most beautiful works of my life, when you are bigger, I will tell you about it.

I am very pleased that you find joy with the piano.

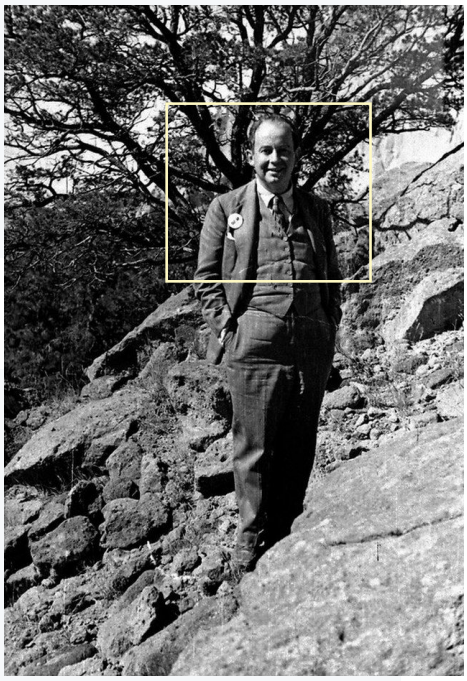
This and carpentry are in my opinion for your age the best pursuits, better even than school. Because those are things which fit a young person such as you very well. Mainly play the things on the piano which please you, even if the teacher does not assign those.

That is the way to learn the most, when you are doing something with such enjoyment that you don't notice that the time passes.

I am sometimes so wrapped up in my work that I forget about the noon meal. . . .

**Be with Tete kissed by your Papa.**

**Regards to Mama.**



## The Kurt Gödel Letter to John von Neumann

**Princeton, 20 March 1956**

**Dear Mr. von Neumann:**

With the greatest sorrow I have learned of your illness. The news came to me as quite unexpected. Morgenstern already last summer told me of a bout of weakness you once had, but at that time he thought that this was not of any greater significance. As I hear, in the last months you have undergone a radical treatment and I am happy that this treatment was successful as desired, and that you are now doing better. I hope and wish for you that your condition will soon improve even more and that the newest medical discoveries, if possible, will lead to a complete recovery.

Since you now, as I hear, are feeling stronger, I would like to allow myself to write you about a mathematical problem, of which your opinion would very much interest me: One

can obviously easily construct a Turing machine, which for every formula F in first order predicate logic and every natural number n, allows one to decide if there is a proof of F of length n (length = number of symbols). Let $\psi(F,n)$ be the number of steps the machine requires for this and let $\varphi(n) = \max_F \psi(F,n)$. The question is how fast $\varphi(n)$ grows for an optimal machine. One can show that $\varphi(n) \geq k \cdot n$. If there really were a machine with $\varphi(n) \sim k \cdot n$ (or even $\sim k \cdot n^2$), this would have consequences of the greatest importance. Namely, it would obviously mean that in spite of the undecidability of the Entscheidungsproblem, the mental work of a mathematician concerning Yes-or-No questions could be completely replaced by a machine. After all, one would simply have to choose the natural number n so large that when the machine does not deliver a result, it makes no sense to think more about the problem. Now it seems to me, however, to be completely within the realm of possibility that $\varphi(n)$ grows that slowly. Since it seems that $\varphi(n) \geq k \cdot n$ is the only estimation which one can obtain by a generalization of the proof of the undecidability of the Entscheidungsproblem and after all $\varphi(n) \sim k \cdot n$ (or $\sim k \cdot n^2$) only means that the number of steps as opposed to trial and error can be reduced from N to log N (or $(\log N)^2$). However, such strong reductions appear in other finite problems, for example in the computation of the quadratic residue symbol using repeated application of the law of reciprocity. It would be interesting to know, for instance, the situation concerning the determination of primality of a number and how strongly in general the number of steps in finite combinatorial problems can be reduced with respect to simple exhaustive search.

I do not know if you have heard that "**Post's problem**", whether there are degrees of unsolvability among problems of the form $(\exists y)\, \varphi(y,x)$, where $\varphi$ is recursive, has been solved in the positive sense by a very young man by the name of Richard Friedberg. The solution is very elegant. Unfortunately, Friedberg does not intend to study mathematics, but rather medicine (apparently under the influence of his father). By the way, what do you think of the attempts to build the foundations of analysis on ramified type theory, which have recently gained momentum? You are probably aware that Paul Lorenzen has pushed ahead with this approach to the theory of Lebesgue measure. However, I believe that in important parts of analysis non-eliminable impredicative proof methods do appear.

I would be very happy to hear something from you personally. Please let me know if there is something that I can do for you. With my best greetings and wishes, as well to your wife,

**Sincerely yours,**



**Kurt Gödel**

**Planck Letter to Schrödinger [2 April 1926]**

**Berlin—Grunewald**
**2 April 1926**

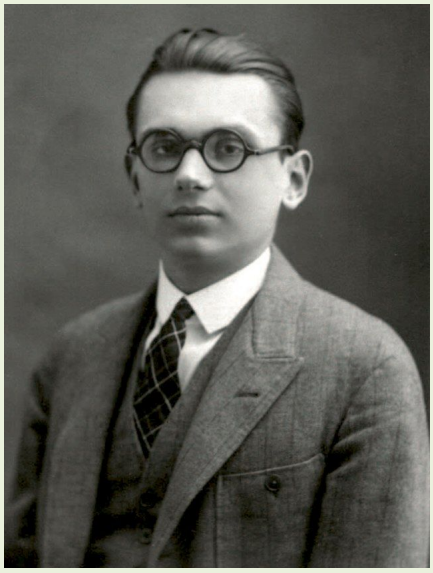
**Dear Colleague,**

Many thanks for the reprint. I read your article the way an inquisitive child listens in suspense to the solution of a puzzle that he has been bothered about for a long time, and I am delighted with the beauties that are evident to the eye, but I have to study it much more closely and in detail to be able to grasp it completely. Besides, I find it extremely congenial that such a prominent role is played by the action function W. I have always been convinced that its significance in physics was still far from exhausted. There is just one little blemish that I would have been glad to see removed. Old Jacobi would have been a little annoyed, despite all his interest, over the alteration of his name. Can it still be changed?

**Yours,**

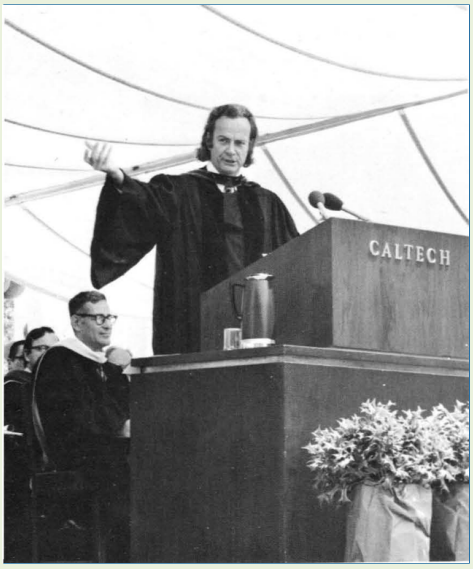


**(Planck)**

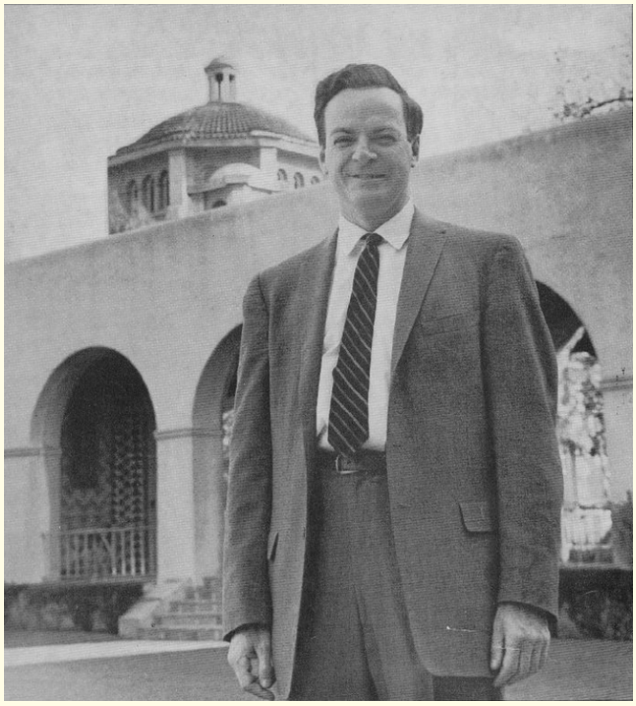


Kurt Gödel

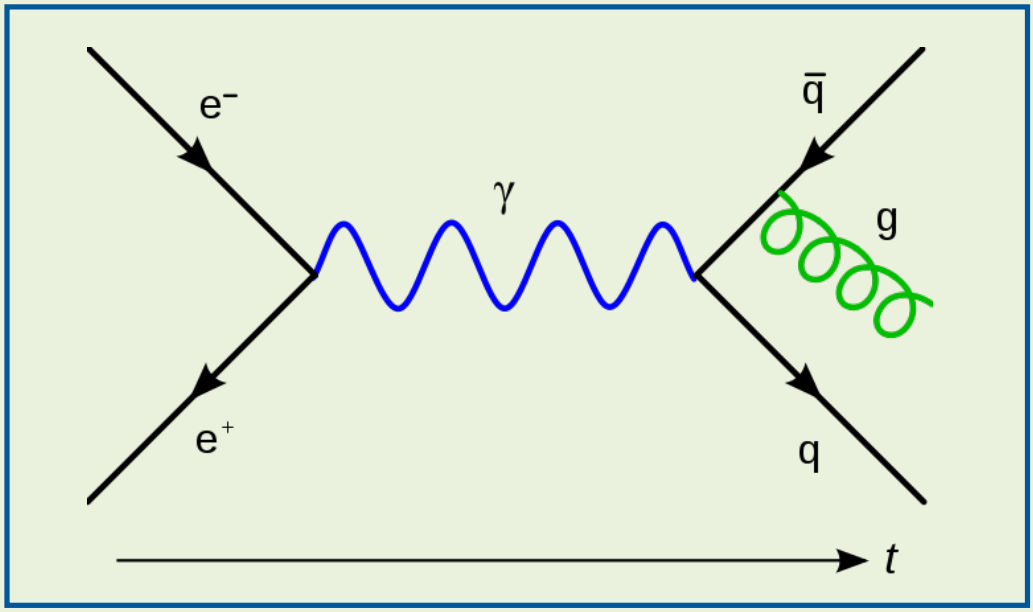
**Kurt Gödel** (1906−1978) was an Austrian mathematician and logician who made groundbreaking contributions to the field of **mathematical logic**. His famous **incompleteness theorems** proved that any consistent mathematical system must contain true statements that cannot be proven within the system, thereby challenging the notion of a complete and consistent system of mathematics. He also made significant contributions to set theory, philosophy of mathematics, and computer science. His work laid the foundation for **modern computer science and artificial intelligence**. Despite his achievements, he struggled with mental illness throughout his life and died in 1978, aged 71.




**Richard Feynman's commencement speech at California Institute of Technology in 1974**



Richard P. Feynman




**A Feynman diagram illustrating the emission of a gluon following the annihilation of an electron and positron**

**General relativity**, Albert Einstein's theory of gravitation, has been extremely successful in explaining a wide range of phenomena, from the behavior of celestial bodies to the properties of black holes. However, it has some limitations and fails to explain certain observations in certain circumstances. Some of the key failures of **General relativity** include:

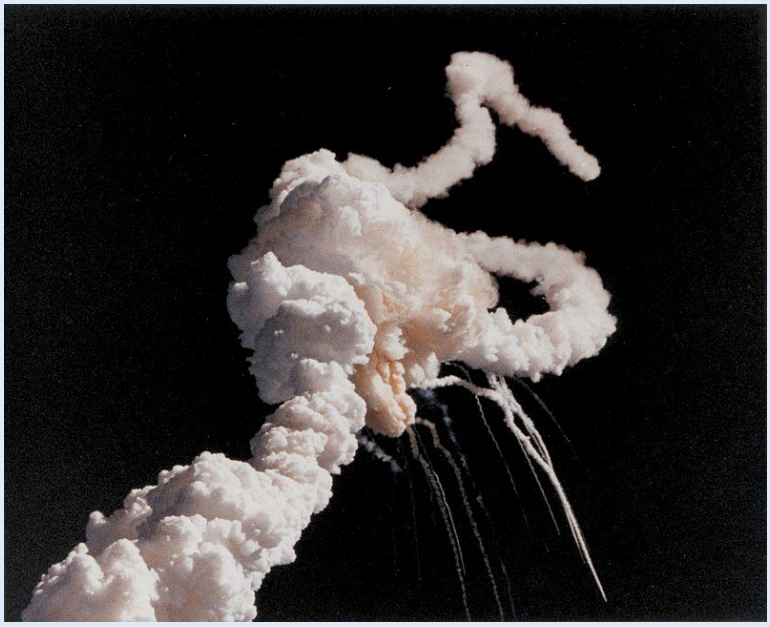
- **Singularities:** General relativity predicts the existence of singularities, points where the curvature of spacetime becomes infinite and the laws of physics break down. This creates a problem for physicists, as they cannot use General relativity to make predictions in these regions.
- **Dark matter and dark energy:** General relativity fails to account for the observed gravitational effects of dark matter and dark energy, which make up the majority of the universe's mass-energy content. This has led to the development of alternative theories, such as modified gravity theories, to explain these observations.
- **Quantum mechanics:** General relativity is a classical theory, meaning it does not incorporate the principles of quantum mechanics. This leads to problems when trying to reconcile GR with quantum theories, such as quantum field theory, which describe the behavior of particles on very small scales.
- **Inadequate description of the early universe:** General relativity cannot be used to describe the very early universe, when it was dominated by quantum mechanical processes. A successful theory of quantum gravity is needed to describe this epoch.

These limitations do not diminish the success of **General relativity** as a theory, but they highlight areas where further research and development is needed to deepen our understanding of the universe.






The gravestone of **Hans Albert Einstein**, located at the **Woods Hole Village Cemetery** in Massachusetts, bears an inscription that honours his life dedicated to his students, as well as his pursuits in research, music, and appreciation of nature.



**The 1986 Space Shuttle Challenger disaster**, the first fatal accident involving an American spacecraft while in flight that resulted in the loss of all seven crew members and highlighted the dangers of space exploration. It led to a comprehensive investigation, significant changes in NASA's safety protocols, and a reevaluation of the risks associated with space missions.

# Space law

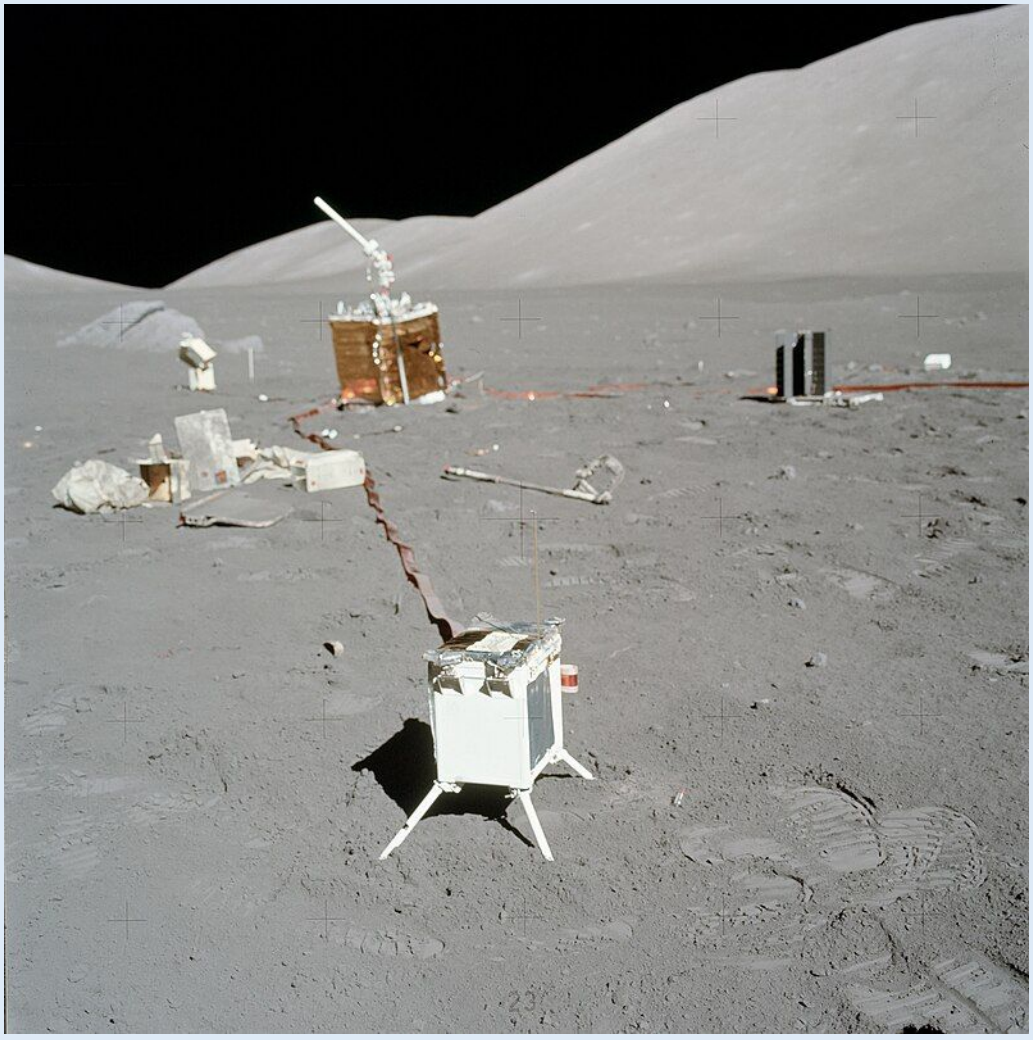
The legal framework that governs space-related activities conducted by countries and private entities. It includes a wide range of international and domestic agreements, rules, and principles that address various aspects of space exploration and use of outer space, the protection of astronauts and space objects, and the management of space debris.



By deploying the **United States flag** during the historic Apollo 11 mission, the first crewed Moon landing, the US did not make a territorial claim on the lunar surface. This act was in full compliance with the Outer Space Treaty, and it served as a symbolic representation of the achievement rather than an assertion of ownership over the Moon. The US, by adhering to the principles of the treaty, demonstrated its commitment to the peaceful use of outer space and the notion that celestial bodies are the common heritage of all humanity.

## Space archaeology

A field of study that focuses on human-made artifacts discovered in space. By examining these artifacts, researchers can uncover valuable insights into the history of space exploration, the cultures of those who ventured into space, and the broader implications of space exploration on Earth.



The **Lunar Surface Experiments Package** (LSEP) left behind by the **Apollo 17 mission** includes scientific equipment and experiments that were conducted on the Moon, representing tangible evidence of human activity on the lunar surface.





**The scientist only imposes two things, namely truth and sincerity, imposes them upon himself and upon other scientists.**

**– Erwin Schrödinger**

## Schrödinger Letter to Planck [8 April 1926]

**Zürich**
**8 April 1926**

**My dear Professor,**

I was indescribably delighted by your kind card of April 2nd. I am especially happy that the basic idea seems plausible to you, and am now very confident that in the course of time it will be worked out in a way that is useable in all respects, no matter how imperfect it may be at present.

I am very ashamed about the dreadful "k", and immediately wrote to the printers; I hope it can still be changed. Many thanks—the worst of it is the ironclad consistency with which I disfigured this hallowed name in five places; it would have been terribly distressing to me.

Thank you very much for kindly sending me your lecture, which I had already read with the greatest interest several days earlier. I was especially captivated by the dramatic force with which you sketch the status of the theory of relativity and the quantum theory—in the third section—and with the way you pick out the key difficulty and make it comprehensible without formulas. Just this difficulty concerning the energy unfortunately still persists, quite unimpaired.

If I did not answer your card, which gave me so much pleasure, at once, it was because I wanted to send along at least a little something that was new. Enclosed are the results for the Stark Effect in H. It seems that the intensities come out completely right. The assumption on which it is based is that the electrical charge density is given by the square of the wave function, and that the normalization integral has the same value for all the individual proper vibrations that belong to one coarse Balmer level. I cannot yet describe the numbers I am sending you as incontestable because the calculation is very involved

and I have not yet checked everything again. In any case Epstein's formula for the splitting comes out completely unaltered (as I already said at the end of my "Second Paper"); also the "Selection Rule for the azimuthal quantum number". Moreover, the "exclusion of zero for the equatorial quantum number" also comes out quite automatically—there is no proper vibration that would correspond to the quantum orbit that collides with the nucleus. It is also very gratifying that although the three unobserved components at relative distances of 5, 6, and 8, are not actually "forbidden" theoretically, they receive an intensity that is 80 to 700 times smaller than that of the weakest observed component, so that their non-appearance becomes very understandable.

I am now calculating $H_\alpha$, $H_\beta$, $H_\gamma$. The calculations are unfortunately terribly difficult to see through and I cannot manage to bring them into a simpler form.

With best compliments and greetings I remain, dear Professor, always

**Yours faithfully,**



**E. Schrödinger**

**Planck Letter to Schrödinger [24 May 1926]**

**Berlin—Grunewald**
**24 May 1926**

**Dear Colleague,**

I have owed you my thanks for some time for your kindly having sent me your last Annalen article on quantization. You can imagine the interest and enthusiasm with which I plunge into the study of these epoch making works, although I now make very slow headway penetrating into this peculiar train of thought. In connection with that I have high hopes of the beneficial influence of a certain amount of familiarity which in

time facilitates the use of new concepts and ideas, as I have often found already. But what especially delights me, and the reason for my really writing you today, is the joyful hope that we may soon have the opportunity to hear you and to talk to you here. As my colleague Grüneisen tells me, your visit to a meeting of the Physical Society has not been cancelled but only somewhat postponed, and it may even still take place this semester. Let me tell you explicitly how much pleasure all of the physicists here would have in hearing you yourself present your new theory and in coming into contact with your ideas. And don't be afraid that we will make too many demands on you and tire you out. I do not know if you are already familiar with Berlin. But I hope you will find that in certain respects life here is freer and more independent than in a smaller city where everyone checks on everyone else, and there is no possibility of completely withdrawing at some time without anybody noticing it.

I should like to express just one little selfish request. In case you can come in July, please not before the 11th. Because at the beginning of July I have to go to Bonn for a few lectures and I would be sad if I missed your visit here as a result. Above all, however, I wish you the relaxation that you need after your demanding labors, and the complete recovery of your powers. I should be especially grateful if, at your convenience, you would send me a brief card with a word about your travel plans.

**In the meantime, with best regards,**

**Yours sincerely,**



**M. Planck**

**Schrödinger Letter to Planck [31 May 1926]**

**Zürich**

**31 May 1926**

**My dear Professor,**

Thank you very much for your kind and extremely gracious letter of the 24th, which now has finally decided me to accept the attractive invitation for this semester, however things may go. I have just written to Mr. Grüneisen. It goes without saying that, so far as I am concerned, a date when you are absent from Berlin is out of the question. Now Mr. Grüneisen was kind enough to point out to me that it might also be possible to consider a slight postponement of the date of the meeting, and since a postponement of the July 9th meeting would surely come too near the end of the semester, as he himself thinks, I have allowed myself to suggest that perhaps the June 25th meeting could be put off until July 2nd. Would that still work out with your trip to Bonn? The 25th of June would not be acceptable to me because from the 21st to the 26th a number of foreign physicists (among them Sommerfeld, Langevin, Pauli, Stern, P. Weiss) are meeting here for lectures and discussions. Now the connections work out so badly that I would have to leave here on the afternoon of the 23rd at the latest, if I do not want to travel through the night directly before the Berlin meeting. And I should not like to do that because then I am often completely exhausted and may possibly speak very badly.

I should be very grateful if you would give me some hints, in just a few words, as to how I should plan my lecture. What I mean is, should I think more of the fact that you and Einstein and Laue are in the audience—a thought without which I should feel uneasy—or should I direct myself more to those gentlemen who are further removed from theoretical work; which would of course have as an inevitable result that those named above (and a considerable number of others) will be very bored. In other words: should I recapitulate in a simplified way what has already been published or, passing over that lightly, talk more about perturbation theory, the Stark effect, and general intensity formulas? (Otherwise I could only mention these latter things briefly at the end, or else it would get to be too long; it takes about an hour for a general survey of the fundamentals, for the purpose of orientation and without much calculation, as I know from our colloquium here).

Naturally I can also do both, if there is the opportunity, one in a general meeting and the other in a more restricted colloquium.

Today I received a very kind and very interesting letter of 13 closely written pages from H. A. Lorentz which I still have to study in detail, of course. He raises a good many interesting questions; however, he does not reject it at all, on the whole, but still appears to be very critical. Lorentz sees one of the chief difficulties in reinterpreting classical mechanics as "wave mechanics" to lie in the fact that the "wave packet" which is to replace the "representative point" of classical mechanics in macroscopic problems, (possibly also in the motion of the electron on paths of slight curvature), that, I say, this wave packet will not remain together, but, on the contrary, will gradually spread into larger volumes by "diffraction", according to general theorems of wave theory. I felt that to be a serious point at first—yet, strange to say, it seems not to be the case, at least not always. For the harmonic oscillator (which always remains the simplest typical example of a mechanical system which one can work with so easily and agreeably), I was able to produce a wave packet, by superposition of a large number of neighboring characteristic oscillations of high order (i.e. high quantum number), which is practically confined to a small spatial region, and which as a matter of fact revolves in precisely the harmonic ellipses described by classical mechanics for an arbitrarily long time without dispersing! I believe that it is only a question of computational skill to accomplish the same thing for the electron in the hydrogen atom. The transition from microscopic characteristic oscillations to the macroscopic "orbits" of classical mechanics will then be clearly visible, and valuable conclusions can be drawn about the phase relations of adjacent oscillations. For the present these phase relations and amplitude relations remain postulates, however; they can naturally also be so arranged that for large quantum numbers a "revolving" mass point does not result: e.g. since the structure is linear it can also be arranged so that two wave groups, revolving independently of one another, result—perhaps the equations are only approximately linear.

A second very delicate question that concerns Lorentz is the energy that is to be assigned to a characteristic oscillation. It is quite certain that the Balmer-Bohr energy value is not to be ascribed to the characteristic oscillation. In general one should not consider the individual characteristic oscillation as the equivalent of the individual Bohr orbit; that is a mistaken parallel, as the above construction shows. The concept "energy" is something that we have derived from macroscopic experience and really only from macroscopic experience. I do not believe that it can be taken over into micro-mechanics just like that, so that one may speak of the energy of a single partial oscillation. The energetic property of the individual partial oscillation is its frequency. Its amplitude must be determined in quite another way—I believe by normalizing the integral of the square of the total excitation to the value of the electronic charge.

Mr. Grüneisen was kind enough to hold out to me the prospect that either you or Mr. von Laue would offer me hospitality. If it doesn't cause too much trouble I am naturally very pleased about it, and in any case I am very grateful for your kind offer. I would strive to give as little inconvenience as possible, and ask that it be so arranged that you are disturbed as little as possible; naturally any improvised lodging you choose is completely adequate for me.

Thank you once again for all the kindness that is always shown me by Berlin in general and by you especially, Professor Planck. With sincere respect, I remain

**Yours faithfully,**



**E. Schrödinger**

**Planck Letter to Schrödinger [4 June 1926]**

**Berlin—Grunewald**

**4 June 1926**

**Dear Colleague,**

I am extremely pleased that you could make up your mind to visit Berlin before the end of this semester, and I know for certain that the rest of the physicists here think the same way.

My colleague Grüneisen informs me that he has some doubts with regard to July 2nd and suggests July 16th instead. I should just like to join him in this. The semester here lasts until the beginning of August so that things are still in full swing in the middle of July and we need not be afraid that many will have already gone away. Grüneisen himself is an exception, to be sure, but he has to set out so early that he would unfortunately miss your visit all the same. But the 16th of July would suit the rest of us very well, and the only question is whether it is suitable for you yourself.

My wife and I would be especially happy if you would stay with us. We hope very much that we will be able to make you comfortable in our house. I shall take care above all that you remain master of your own actions to the greatest possible extent, and especially that, at those times over and above the "official" periods dedicated to the Physical Society, you have the opportunity to withdraw and to occupy yourself as you see fit. I know from experience how pleasant it often is to have a possibility of this kind. Moreover, my house stands at your disposal night and day for as long as you are inclined to stay.

You also talk about the level at which your lecture should best be given, or rather at which it should begin. I would like to propose, in agreement with my colleagues, that you imagine your audience to be students in the upper classes who, therefore, have already had mechanics and geometrical optics, but who have not yet advanced into the higher realms; to whom, therefore, the Hamilton-Jacobi differential equation, if they are acquainted with it at all, signifies a difficult result of profound research, deserving of reverence, and not by any means something to be taken for granted. Under no circumstances, however, should you be afraid that any one of us will consider one

sentence of yours to be superfluous. For even if the sentence should not be necessary for an understanding of your train of thought, it would always offer the particular interest of seeing what special paths your thought takes and which particular forms your perception favors. For all of us the main point of your lecture will be what you yourself in your letter designated as a general survey of the fundamentals for the purpose of orientation without much calculation and without many individual problems. Perhaps it would be easier and more natural for you to carry this out, if on the other day, Saturday morning the 17th of July, you were to give a second lecture in our Colloquium, aimed at more special matters with supplements and continuations of the lines of thought you will have described at the more general meeting. I hope that this seems suitable to you, since you already indicated such a possibility yourself. That can very easily be arranged, and I ask you only to let me know so that we can take care of matters.

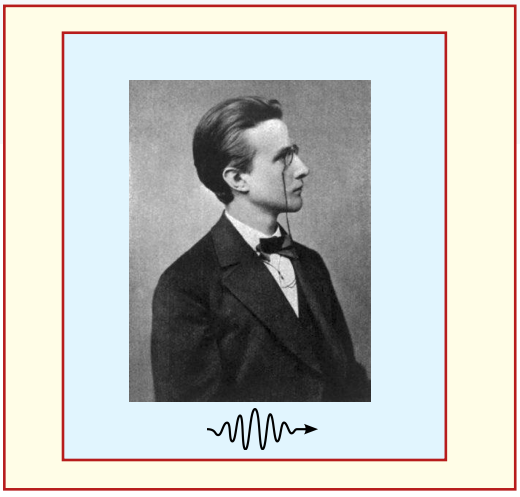
What a cross-fire of critical, enthusiastic, and questioning acclamations might now besiege you! But still, it is a thing with incredible prospects. I see that you have already energetically taken hold of the big question of whether and under what conditions a wave packet will remain intact. I have such a feeling that for closed systems it is the boundary conditions that take care of the conservation [of the wave packet], whereas a satisfactory solution for phenomena in an unbounded space seems to me to be possible only on the basis of new assumptions. That, however, is a cura posterior.

In the meantime my cordial greetings and the friendly request that you write me the day and hour that you arrive here.

**Yours faithfully,**

Max Planck

**(Planck)**



The earth is not a **perfect sphere**. As the radius of the earth increases from the poles to the equator, the value of $g = \frac{GM}{R^2}$ becomes greater at the poles than at the equator. Therefore, for practical purposes we take **acceleration due to gravity** as a constant.

**Weight of the object on the moon = $\frac{1}{6}$ × its weight on the earth.**

Inside the sun, we have **N** protons:

$$\mathbf{N}_{\text{protons}} = \frac{\text{Mass of the sun}}{\text{Mass of the proton}} = \frac{1.98910 \times 10^{30}\ \text{kg}}{1.67262 \times 10^{-27}\ \text{kg}} \approx 1.1892 \times 10^{57}$$

The number of nuclear fusion reactions inside the sun:

$$\mathbf{N}_{\text{reactions}} \approx \frac{1.1892 \times 10^{57}}{4} \approx 2.9730 \times 10^{56}$$

**If the nuclear fission chain reaction is not controlled, a nuclear explosion will occur.**

## Space industry

A rapidly growing sector that includes all economic activities related to space exploration, satellite deployment, space research, and different space mission-related services. It includes both government and corporate space agencies that collaborate to develop, construct, and launch spacecraft, satellites, and other components into space.



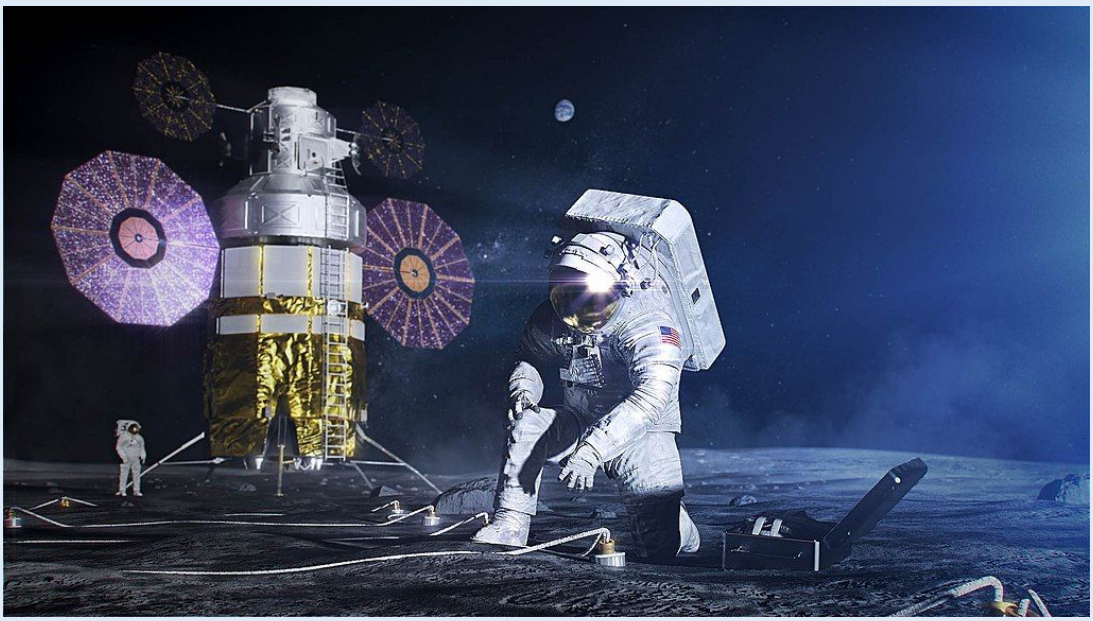
**A batch of 60 Starlink satellites in space**, launched and deployed by **SpaceX**, as part of its ongoing efforts to provide high-speed internet services to users on the planet earth.

## Lunar resources

The valuable materials and substances that can be found on the surface or beneath the surface of the Moon that hold significant potential for future human activities, such as lunar exploration, colonization, and even space missions beyond the Moon.

## ✓ Artemis program

A space exploration initiative led by **NASA**, the United States' space agency. Its ultimate goal is to establish a sustainable human presence on the lunar surface and to use the Moon as a stepping stone for future crewed missions to Mars and beyond.



In this artist's depiction of an **Artemis mission**, an astronaut is depicted wearing the **xEMU spacesuit** while performing an **Extravehicular Activity** (EVA) on the lunar surface. The scene showcases the futuristic vision of human exploration on the Moon through the Artemis program, where astronauts will venture outside their spacecraft, equipped with advanced spacesuits, to conduct various tasks and scientific experiments in the challenging lunar environment.

## Deep Space Transport

A **conceptual spacecraft** or **vehicle** capable of sustaining astronauts for extended periods, providing life support systems, protection from space radiation, and the ability to carry sufficient supplies and equipment for the duration of the mission. It is designed for crewed missions beyond Earth's orbit, specifically for long-duration travel to destinations such as Mars or other deep space locations.

## Space advertising

The practice of promoting products, services, or brands in the outer space environment. This form of advertising typically involves placing logos, slogans, or images on spacecraft, rockets, satellites, or other space-based assets, with the intention of reaching a wider audience and creating brand visibility on a global scale.




In this image, astronaut **Tony England** is depicted in the microgravity environment of space, sipping Coca-Cola from a **specially designed can** that allows consumption in zero gravity conditions.

## Subdwarf

A star containing few elements heavier than helium that is smaller and dimmer than a **main sequence star** of the same temperature.

A star that sustains nuclear fusion of hydrogen in its core, maintaining a stable balance between the outward pressure generated by this fusion and the inward gravitational forces.

## Space traffic management

The regulation and coordination of space activities to ensure the safety and sustainable utilization of space resources. It involves implementing regulations and protocols to ensure that space operations are conducted in a manner that minimizes risks and promotes long-term viability of space resources.

## Space diplomacy

The combined effort of knowledge, technology, and legislation within the realm of **science diplomacy**, applied to facilitate and enhance the expanded exploration of space.

The use of scientific collaborations, knowledge exchange, and cooperative efforts in international relations to address global challenges, build trust, and foster peaceful relationships between nations.

## Militarisation of space

Deploying and advancing weaponry and military technology in the outer space environment.



Artistic depiction of a **Global Positioning System (GPS) satellite** in Earth orbit.

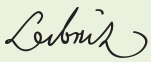
→ Provides your precise location on Earth



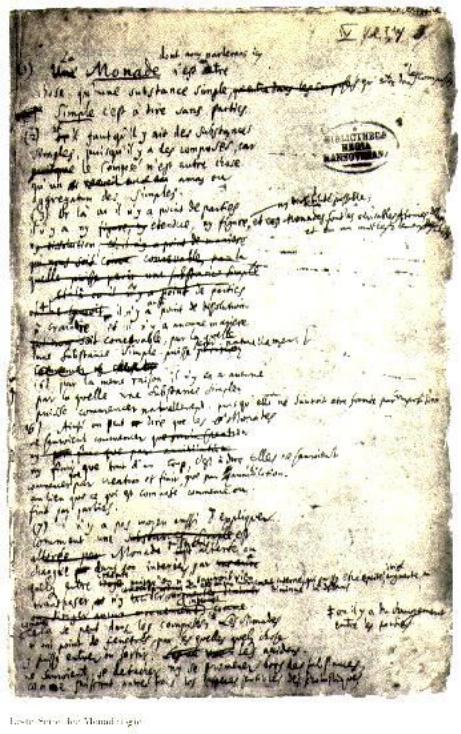
**Pluto's moon Charon as viewed by NASA's New Horizons spacecraft on July 13, 2015**





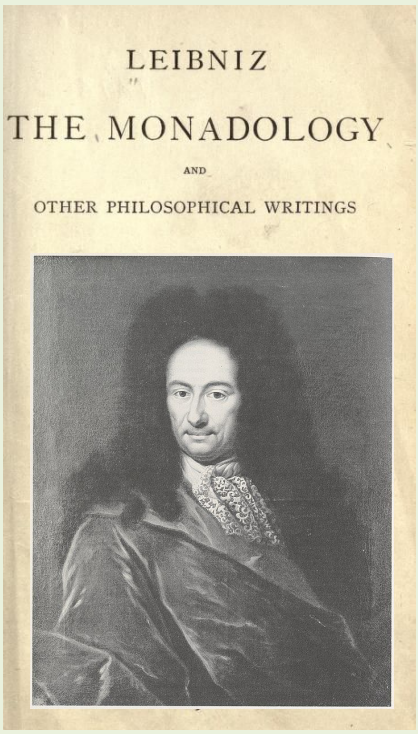



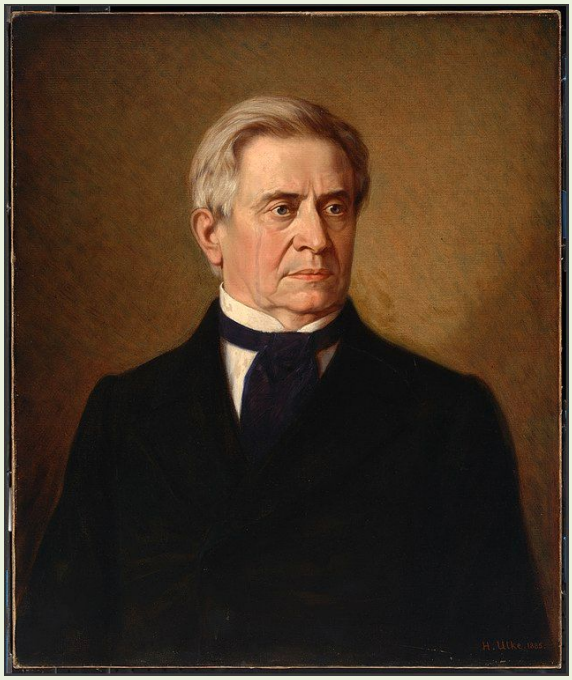
**Gottfried Wilhelm Leibniz** (1646–1716) was a German philosopher, mathematician, and polymath. He is known for his contributions to calculus, which he developed independently of **Isaac Newton**, as well as his work in logic, metaphysics, and theology. **Leibniz** is also credited with inventing the binary system, which is the basis for modern computing. He was a prolific writer and corresponded with many of the leading intellectuals of his time. **Leibniz's philosophy** emphasized the concept of the monad, which he believed to be the basic unit of all reality. His ideas had a profound influence on subsequent thinkers in many fields.



**A page from Leibniz's manuscript of the Monadology**

The **Monadology** is a short work by **Gottfried Wilhelm Leibniz**, originally published in 1714. It is a philosophical treatise on metaphysics and the nature of reality. The manuscript is written in Leibniz's own handwriting, and consists of 90 numbered paragraphs. **The text is divided into three sections.** The **first section** explains the concept of **monads**, which are indivisible, non-physical units of reality. According to **Leibniz**, each monad has its own unique set of perceptions, and the entire universe is composed of an infinite number of monads, all of which are interconnected. The **second section** of the manuscript discusses the principles of causality and pre-established harmony. **Leibniz** argues that all events are caused by previous events, but that the universe is pre-programmed to ensure that everything happens in accordance with a predetermined plan. The **final section** of the manuscript is a brief conclusion, in which **Leibniz** summarizes his key ideas and emphasizes the importance of studying metaphysics in order to understand the true nature of reality. Overall, the manuscript of the **Monadology** is a fascinating glimpse into the mind of one of the most important philosophers of the 17th and 18th centuries.







**Joseph Henry** (1797−1878) was an American scientist and inventor who is best known for his contributions to the field of electromagnetism. He was born in Albany, New York and received his education at **Albany Academy**. After working as a teacher for several years, he was appointed professor of **natural philosophy** (the term used for physics at the time) at the College of New Jersey (now Princeton University) in 1832. Henry's research focused primarily on electromagnetism, and he made several important discoveries in this field. In 1828, he discovered the **phenomenon of self-induction**, which occurs when a changing electric current in a coil of wire creates a magnetic field that induces a current in the same coil. He also discovered electromagnetic induction independently of **Michael Faraday**, but Faraday published his results first. Henry is perhaps best known for his invention of the **electromechanical relay** in 1835. This device uses an **electromagnet** to open or close a switch, and it was an important component of early telegraph systems. He also invented the **first practical electric motor** in 1831, which used electromagnets to turn a rotor. In addition to his scientific work, Henry was a noted educator and advocate for science education. He served as the first secretary of the **Smithsonian Institution**, where he worked to establish a national museum of science and to promote scientific research and education. Today, **Henry's name** is widely recognized in the field of electromagnetism, and his work laid the foundation for many important developments in electrical engineering and telecommunications.

## Kepler's Third Law for Circular Orbits:

Let us consider a planet of mass **m** orbiting a star of mass **M** in a circular orbit. The **gravitational force** between the planet and the star provides the necessary centripetal force for the planet to stay in its orbit. The **gravitational force** between the planet and the star is given by **Newton's law of universal gravitation**:

$$F_G = \frac{GMm}{r^2}$$

where $F_G$ is the gravitational force, **G** is the gravitational constant, **M** is the mass of the star, **m** is the mass of the planet, and **r** is the distance between the planet and the star. Since the planet is in a circular orbit, the **gravitational force** provides the centripetal force:

$$\frac{GMm}{r^2} = m \times a_{\text{centripetal}}$$

where $a_{\text{centripetal}}$ is the centripetal acceleration of the planet. The **centripetal acceleration** can be expressed in terms of the orbital period **T** and the radius of the circular orbit **r**:

$$a_{\text{centripetal}} = \frac{4\pi^2 r}{T^2}$$

$$\frac{GMm}{r^2} = m \times \frac{4\pi^2 r}{T^2}$$

Solving for $T^2$ yields:

$$T^2 = \frac{4\pi^2}{GM} \times r^3$$

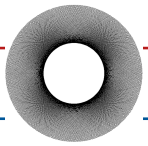
$$T^2 \propto r^3$$

The square of the orbital period of a planet in a circular orbit is directly proportional to the cube of its average distance from the star.

# Does the Universe's expansion slow down over time?

The expansion of the Universe has been observed to be accelerating, rather than slowing down, over time. This acceleration is believed to be caused by a mysterious force known as **dark energy**, which is thought to permeate the entire Universe and push galaxies apart from one another. The discovery of this acceleration was unexpected and led to the development of a new model of the Universe called the **Lambda-CDM model**. In this model, the Universe is thought to be composed of around 68% dark energy, 27% dark matter, and 5% ordinary matter, with the dark energy driving the accelerating expansion. It is possible that the acceleration of the expansion could eventually slow down or even reverse, but this is uncertain and depends on the properties of dark energy, which are not yet fully understood. Some theories suggest that the expansion could continue to accelerate indefinitely, leading to a **"Big Rip"** in which the Universe eventually tears itself apart. However, this is currently a topic of active research and debate in the field of cosmology.

- When the universe was very dense and very hot, General Relativity and Quantum Mechanics were not applicable, but instead Quantum Gravity ruled the world.
- Copernicus brought the idea of a **Heliocentric world**, and Kepler showed that planets move on ellipses around the sun.
- In a flat universe the sum of all angles in a triangle is $180^o$, in a closed geometry it is larger than $180^o$, and an open geometry it is smaller than $180^o$.



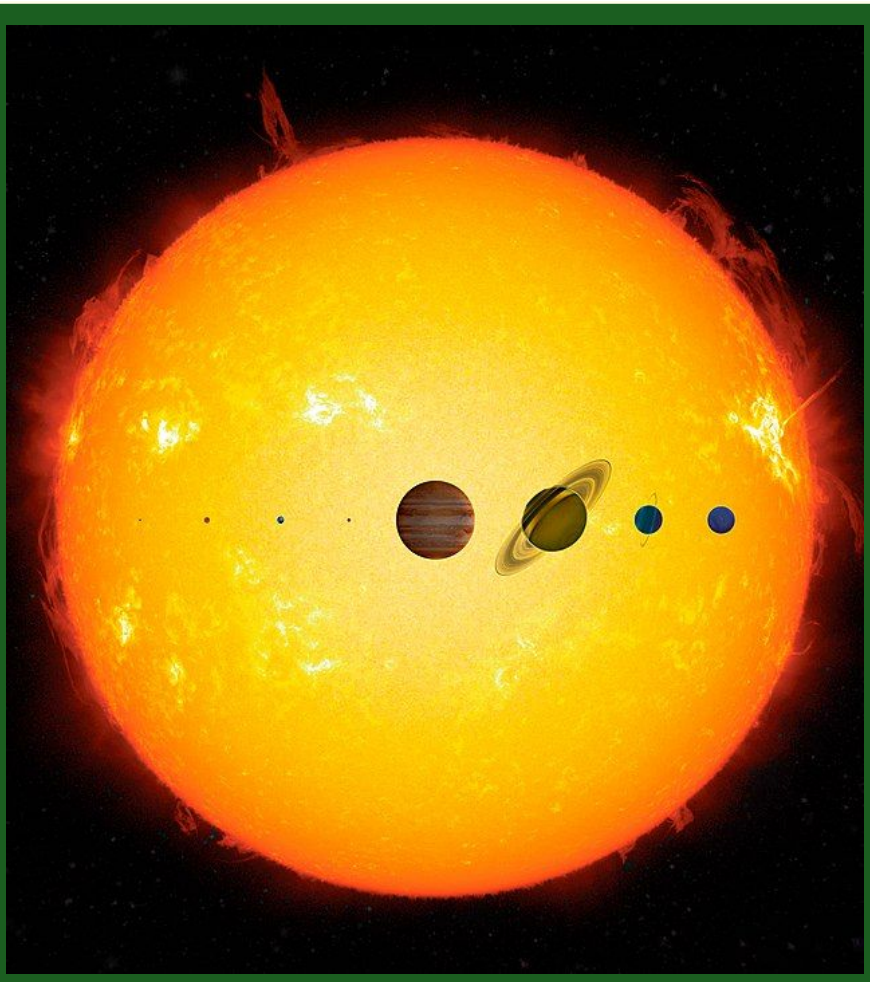
**Karl Raimund Popper** [Austrian-born British philosopher, academic and social commentator] mentions five things that are altogether unpredictable:

- The production of heavier elements in the stars
- The emergence of living organisms
- The emergence of sentient animal life
- The emergence of human consciousness and theories of self and death in humans
- The emergence of explanatory myths, religions, scientific theories, and works of art.

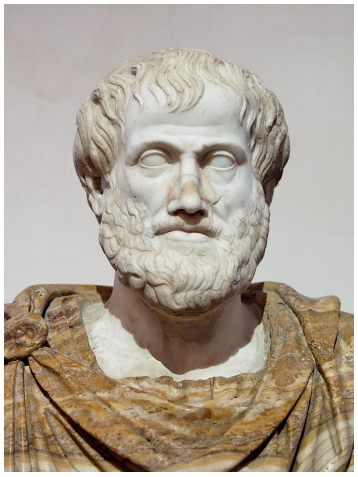
If the universe expands, it was very dense and hot before

**Then there should be cold / low frequency light around us.**

The CMB is the oldest light in the universe, and it pervades all of space, filling it with a faint glow at a temperature of just 2.73 degrees above absolute zero.



**All 8 planets in a size comparison with the Sun in scale**



**Aristotle**

**(384−322 BC)**

The earth is spherical in shape.



**Aristarchus**

**(312−230 BC)**

The universe, by Heaven's decree
Was never formed in time gone by,
But is, has been, shall ever be —
For so say Bondi, Gold and I.
Stay, O Cosmos, O Cosmos, stay the same!
We the Steady State proclaim!

**– George Gamow**

The Universe is Sun-centered.

## Rayleigh scattering

The amount of scattering of light is inversely proportional to the fourth power of its wavelength.

(Shorter the wavelength, higher the scattering)

The size of the Earth has some variations.

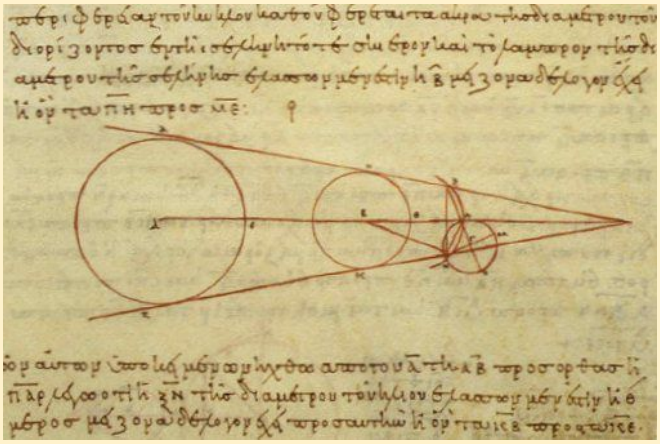


**Eratosthenes**

**(276−194 BC)**



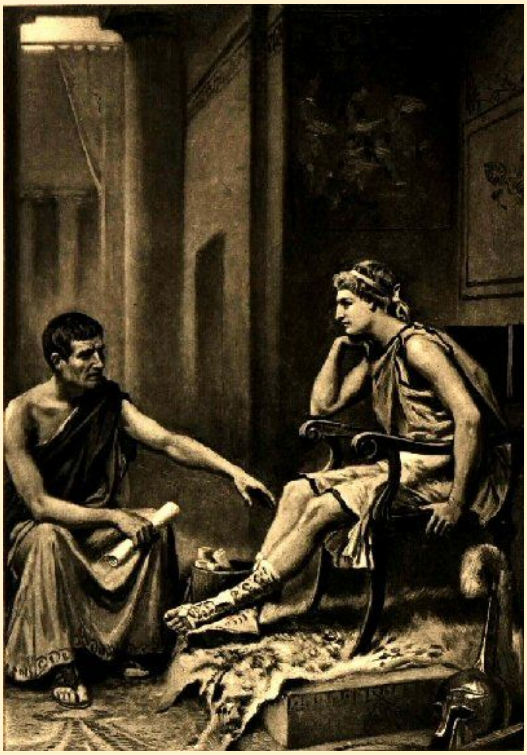
**Eratosthenes teaching in Alexandria**



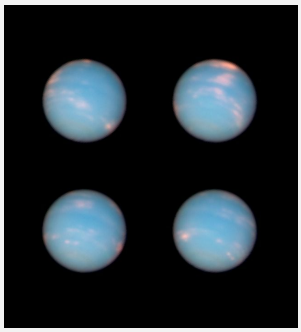
**Aristarchus's third-century BC calculations on the relative sizes of (from left) the Sun, Earth, and Moon, from a tenth-century AD Greek copy**



✓ Jupiter and its four planet-size moons - called the Galilean satellites



✓ Aristotle tutoring Alexander the Great



**The four sides of Neptune captured by the Hubble Space Telescope on July 12, 2011**



**Galileo Demonstrating the New Astronomical Theories at the University of Padua**

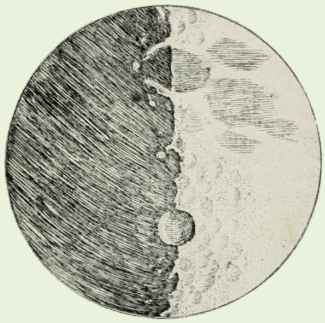
## ✓ Did you know?

The **Milky Way** has indeed grown over time through the process of merging with and accreting material from other galaxies. In fact, it is believed that many of the stars that make up the **Milky Way** today were originally part of other galaxies that were consumed by our galaxy over time. It is currently consuming material from the **Magellanic Clouds** as well as stars from a small galaxy known as the **Sagittarius Dwarf Spheroidal**.

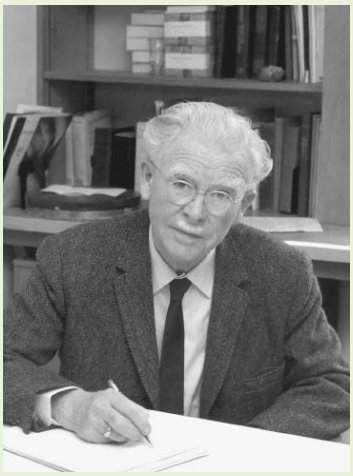
**Pluto was reclassified from planet to dwarf planet in 2006 and is named after the Roman deity of the underworld.**




The man who discovered Pluto, Clyde Tombaugh, is seen here holding a homemade 9-inch telescope at his family's farm.



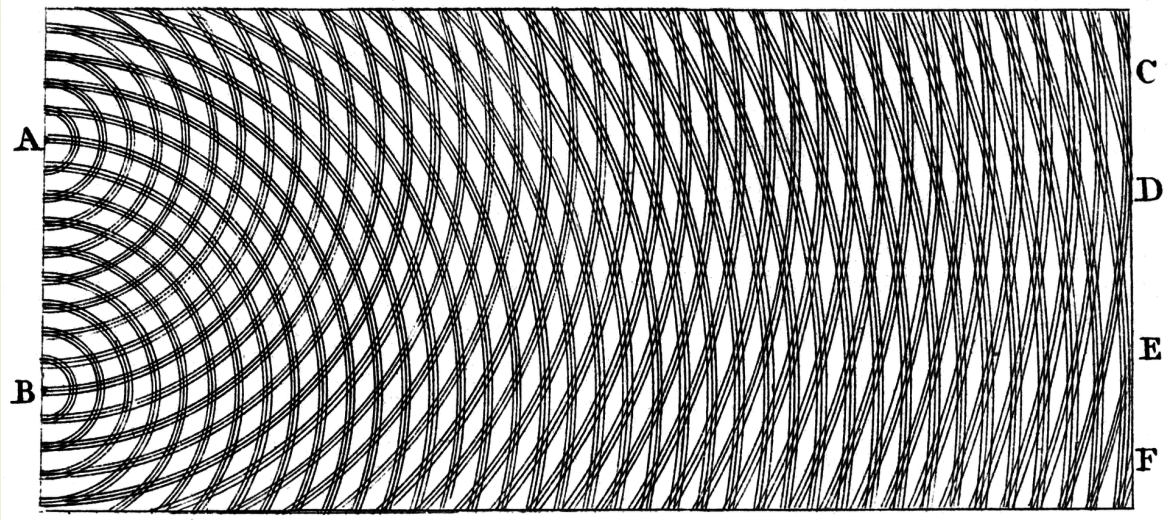
**One of Galileo Galilei's drawings of the moon**



**Scott E. Forbush** (1904−1984) was an **American physicist** who made significant contributions to the field of cosmic ray research. He is best known for his discovery of the phenomenon now known as the **Forbush decrease**, which describes a temporary reduction in the intensity of cosmic rays reaching the Earth's surface, caused by the presence of a coronal mass ejection from the Sun. **Forbush's work** on **cosmic rays** helped to advance our understanding of the Sun's magnetic field and its interactions with the Earth's magnetic field, and laid the groundwork for further research into the effects of cosmic rays on climate and weather patterns.

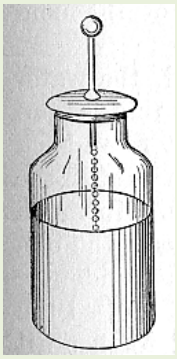


**Thomas Young** (1773−1829) was a British scientist and polymath who made significant contributions to a wide range of fields, including physics, optics and mechanics. Young is best known for his work on the **interference of light**, which helped to establish the **wave theory of light**. He conducted the famous **double-slit experiment**, which demonstrated the interference pattern of light and provided strong evidence for the wave nature of light. He also made important contributions to the understanding of the eye and vision, including the discovery of the phenomenon of **astigmatism**.




**Thomas Young's sketch of two-slit diffraction, which he presented to the Royal Society in 1803**





An early 20th-century illustration of a Leyden jar.

**Pieter van Musschenbroek** (1692−1761) was a Dutch scientist who made significant contributions to the fields of physics and electricity. He is perhaps best known for his invention of the **Leyden jar**, a device for storing electrical charge that became one of the most important tools in the study of electricity in the 18th century. **Musschenbroek** also conducted extensive research into the properties of electric charge and discovered the **principle of capacitance**, which describes the ability of a system to store electrical charge. His work laid the foundations for further research into **electricity and electromagnetism**, and helped to pave the way for many of the technological innovations of the modern era.

## Ten most common elements in the Milky Way Galaxy

estimated based on spectroscopic observations and current scientific knowledge

| Z | Element | Mass fraction in parts per million |
|---|---|---|
| 1 | Hydrogen | 739,000 |
| 2 | Helium | 240,000 |
| 8 | Oxygen | 10,400 |
| 6 | Carbon | 4,600 |
| 10 | Neon | 1,340 |
| 26 | Iron | 1,090 |
| 7 | Nitrogen | 960 |
| 14 | Silicon | 650 |
| 12 | Magnesium | 580 |
| 16 | Sulfur | 440 |

## Planck orbital momentum:

**Planck orbital momentum = Planck mass × Planck speed × Planck length**

$$C_{Planck} = \sqrt{\frac{\hbar c}{G}} \times c \times \sqrt{\frac{\hbar G}{c^3}}$$

$$C_{Planck} = \hbar \approx 1.054\ 571\ 726 \times 10^{-34}\ Js$$

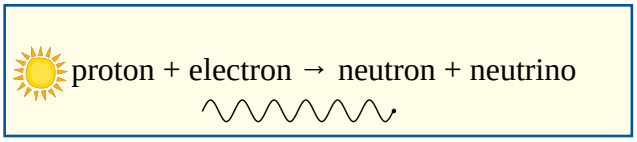
**The angular momentum quantum**

$$\frac{\text{Energy of photon}}{\text{Angular frequency of photon}} = \textbf{Planck orbital momentum}$$

Uncertainty in the position of the particle × Uncertainty in the momentum of the particle $\geq \frac{\textbf{Planck orbital momentum}}{2}$

Uncertainty in the energy of the particle × Uncertainty in the time at which that energy was measured $\geq \frac{\textbf{Planck orbital momentum}}{2}$

✔ When $\rho \approx 10^9$ Kg/m$^3$, the electrons become relativistic ($pc >> m_0c^2$). Soon thereafter, the energetic relativistic electrons convert protons in the iron nuclei into neutrons by process of electron capture:




This reaction proceeds only if the kinetic energy of the electron:

$$KE = (m_nc^2 - m_pc^2 - m_ec^2) = 0.78 \text{ MeV}$$

$$\frac{m_ec^2}{\sqrt{1-\frac{v^2}{c^2}}} - m_ec^2 = (m_nc^2 - m_pc^2 - m_ec^2)$$

$$\left(\frac{m_e}{m_n - m_p}\right)^2 = 1 - \frac{v^2}{c^2}$$

$$v = c\sqrt{1 - \left(\frac{m_e}{m_n - m_p}\right)^2}$$

The relativistic mass of the electron is given by:

$$m = \frac{m_e}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$1 - \frac{v^2}{c^2} = \frac{m_e^2}{m^2}$$

If $m = \sqrt{\frac{\hbar c}{G}} = M_{Planck}$:

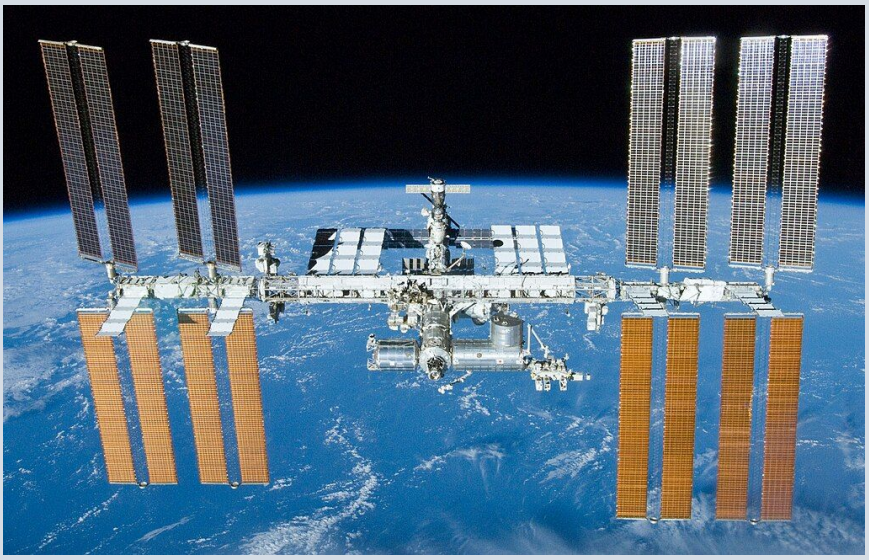
$$v = c\sqrt{1 - \alpha_G}$$

- $\alpha_G$ is the gravitational coupling constant for the electron
- v → velocity a electron must travel so that its relativistic mass to be equal to **Planck mass**

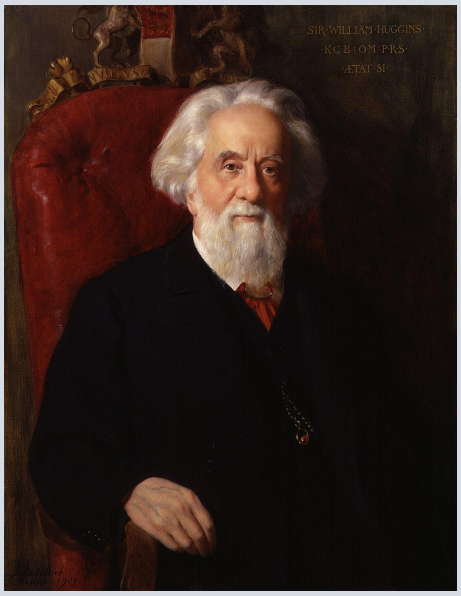


Cecilia Payne Gaposchkin

**Cecilia Payne-Gaposchkin** was an influential astronomer and astrophysicist who made significant contributions to our understanding of the composition of the Sun and stars. Her doctoral thesis **"Stellar Atmospheres: A Contribution to the Observational Study of High Temperature in the Reversing Layers of Stars"** laid the foundations for our understanding of the composition of stars, including the Sun. At the time, it was widely believed that the chemical composition of the Sun and stars was similar to that of the Earth, with higher proportions of heavier elements like iron. However, **Payne's groundbreaking work** challenged this notion. Her analysis of **stellar spectra**, which is the study of the light emitted by stars, led her to a **groundbreaking conclusion** that stars are predominantly composed of hydrogen and helium, with much smaller amounts of heavier elements.



The **International Space Station** is seen above Earth, as captured in 2010 by the departing crew of the Space Shuttle Atlantis.



✓ Sir William Huggins



✓ Margaret Lindsay Huggins

**Sir William Huggins** was a British astronomer and pioneer in the field of astrophysics. He is renowned for his work in spectroscopy, which involves studying the interaction of light with matter to analyze the composition and properties of celestial objects. Huggins and his wife, **Margaret Lindsay Murray**, collaborated extensively on astronomical research. Together, they made significant contributions to our understanding of stars, nebulae, and galaxies. **Huggins** was among the first astronomers to use **spectroscopy** to examine the light emitted by celestial bodies, paving the way for the field of astrophysics.

✓ **Alpha Decay:**

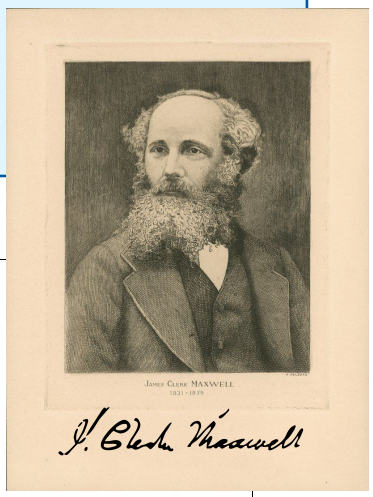
$${}^{A}_{Z}X \text{ (Parent nucleus)} \longrightarrow {}^{A-4}_{Z-2}Y \text{ (daughter nucleus)} + {}^{4}_{2}He \text{ (alpha particle)}$$

✓ **Neutron capture:**

$${}^{1}_{0}n \text{ (Neutron)} + {}^{A}_{Z}X \longrightarrow {}^{A}_{Z}X^{*} \text{ (excited state)} \xrightarrow{\text{gamma decay}} {}^{A+1}_{Z}X + \gamma$$

"The true logic of this world is in the calculus of probabilities."

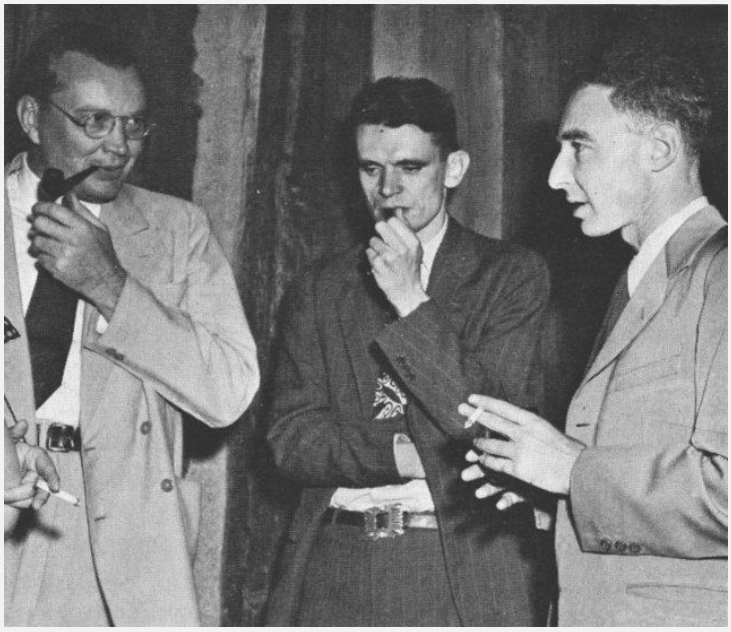
— **James Clerk Maxwell**




$$\sqrt{\frac{\hbar G}{c^3}} \longrightarrow$$ **The fundamental limit on the resolution of space.**

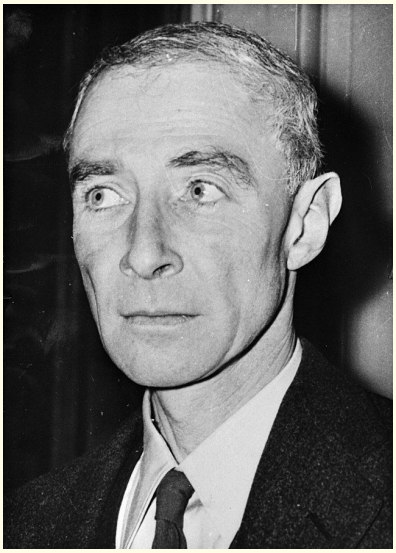
**At length scales smaller than the Planck length, it is believed that the structure of space and time becomes inherently fuzzy and uncertain.**

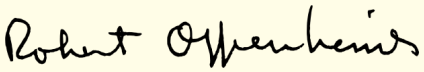
**Sir Isaac Newton** (1642–1726) created most of his major discoveries in 1665–1667, shortly once receiving his Bachelor's degree from the University of Cambridge. Though Newton earned backing for any study, the University closed as a result of the plague, and he had to come to his family range in Lincolnshire for eighteen months. it had been throughout this point that he discovered his theory of colours, the law of gravitation, and calculus. In later years, with the exception of following analysis in physics and arithmetic, Newton devoted a lot of effort to alchemy and to Scriptural studies.

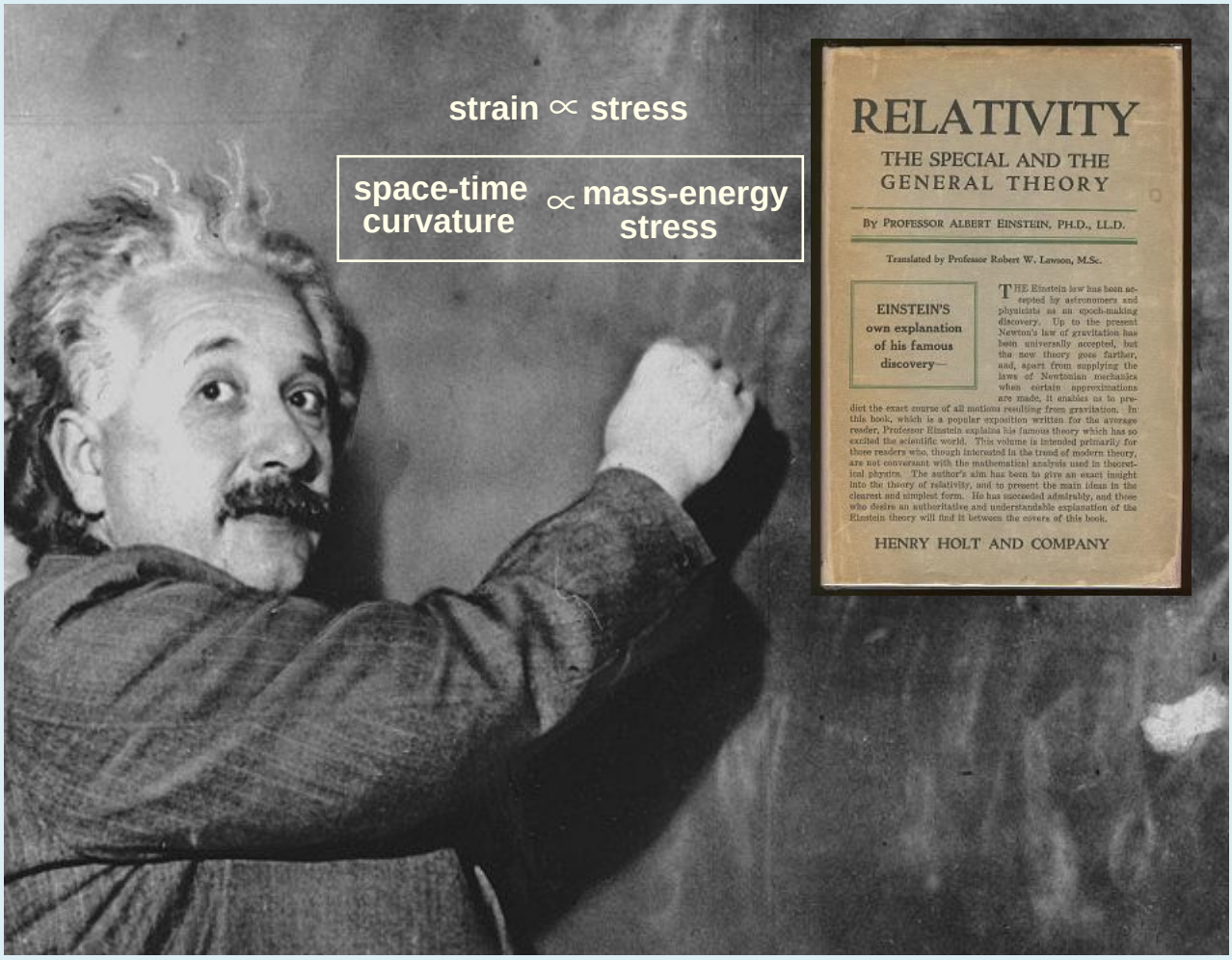


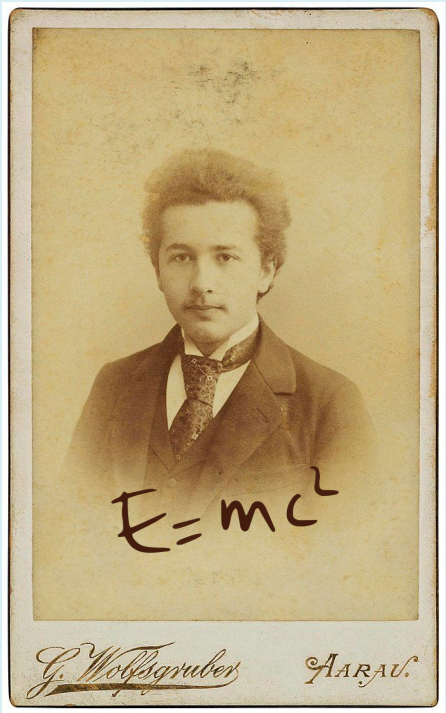
**Eric Jette, Charles Critchfield, and J. Robert Oppenheimer at Los Alamos**

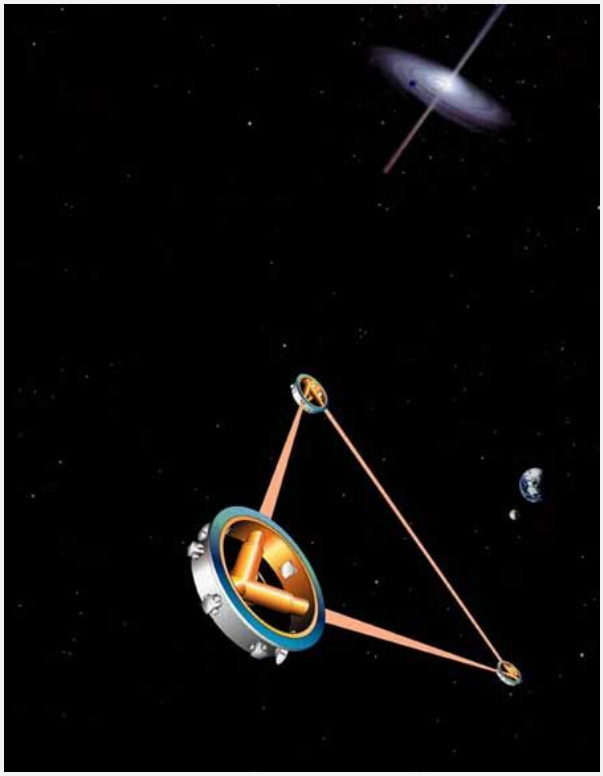
**Dr. J. Robert Oppenheimer** was an American theoretical physicist and professor of physics at the University of California, Berkeley. He is best known for his role as the scientific director of the Manhattan Project, the US government research project that developed the first atomic bomb during **World War II**. **Oppenheimer** was born on April 22, 1904, in New York City. He studied at Harvard University, where he received his undergraduate degree in chemistry in 1925 and his Ph.D. in physics in 1929. He went on to teach at the University of California, Berkeley, and at the California Institute of Technology before being appointed scientific director of the Manhattan Project in 1942. During the **Manhattan Project**, **Oppenheimer** led a team of scientists at the Los Alamos Laboratory in New Mexico, where they developed the first atomic bomb. The success of the project made **Oppenheimer** a national hero, but he also became a controversial figure due to his opposition to the development of the hydrogen bomb and his left-leaning political views. After the war, **Oppenheimer** continued to work in academia, but he also became involved in government policy and international relations. He served on the **General Advisory Committee of the Atomic Energy Commission** and was a vocal advocate for arms control and nuclear disarmament. However, his political views and associations with left-wing groups led to accusations of disloyalty and communist sympathies, which culminated in a security clearance hearing in 1954. **Oppenheimer's security clearance** was eventually revoked, and he was effectively barred from working on government projects. **Oppenheimer** continued to work in academia until his death from throat cancer on February 18, 1967. He is remembered as one of the greatest physicists of the 20th century, as well as for his role in the development of the atomic bomb and his contributions to the fields of nuclear physics and international relations.





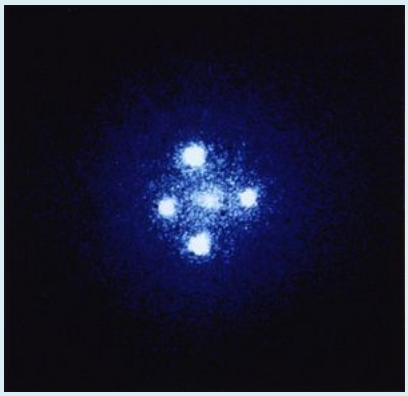

strain ∝ stress
space-time curvature ∝ mass-energy stress
RELATIVITY
THE SPECIAL AND THE GENERAL THEORY
By Professor Albert Einstein, Ph.D., LL.D.
Translated by Professor Robert W. Lawson, M.Sc.
EINSTEIN'S own explanation of his famous discovery—
THE Einstein law has been accepted by astronomers and physicists as an epoch-making discovery. Up to the present Newton's law of gravitation has been universally accepted, but the new theory goes farther, and, apart from supplying the laws of Newtonian mechanics when certain approximations are made, it enables us to predict the exact course of all motions resulting from gravitation. In this book, which is a popular exposition written for the average reader, Professor Einstein explains his famous theory which has so excited the scientific world. This volume is intended primarily for those readers who, though interested in the trend of modern theory, are not conversant with the mathematical analysis used in theoretical physics. The author's aim has been to give an exact insight into the theory of relativity, and to present the main ideas in the clearest and simplest form. He has succeeded admirably, and those who desire an authoritative and understandable explanation of the Einstein theory will find it between the covers of this book.
HENRY HOLT AND COMPANY


E=mc²
G. Wolfsgruber
Aarau

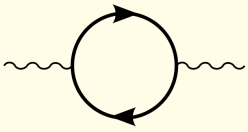


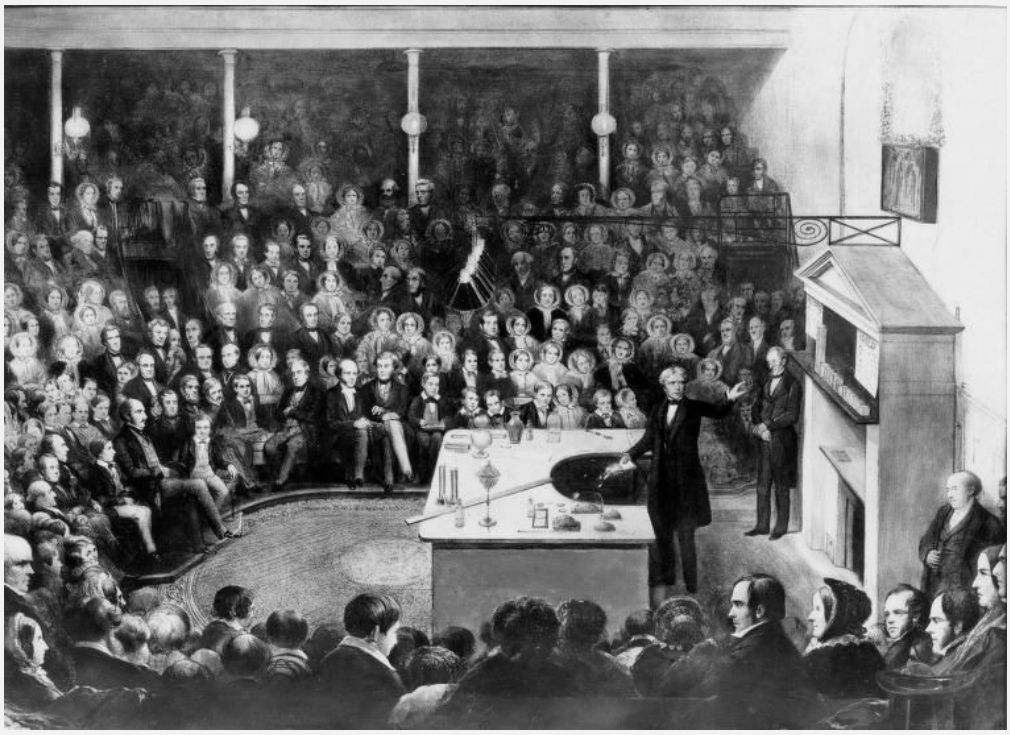
✓ **LISA, a space-based gravitational wave detector, as depicted by an artist**

The **Einstein Cross** is a rare astronomical phenomenon that occurs when the light from a distant quasar is bent and magnified by the gravitational field of a foreground galaxy, producing four distinct images of the same quasar arranged in a cross-like pattern around the galaxy. The phenomenon is named after **Albert Einstein**, who first predicted the **gravitational lensing effect** in his **theory of general relativity**. The Einstein Cross was first observed in 1985, when astronomers discovered four identical images of a quasar known as **Q2237+0305**, located about 8 billion light-years away from **Earth**, arranged in a cross-like pattern around a foreground galaxy. The gravitational lensing effect that produces the **Einstein Cross** occurs when the massive foreground galaxy acts like a giant lens, bending and magnifying the light from the distant quasar. The effect is similar to how a magnifying glass can focus sunlight to create a brighter image. The **Einstein Cross** is a rare and striking example of gravitational lensing, and has provided astronomers with valuable insights into the structure and properties of galaxies, as well as the nature of dark matter, which is thought to be responsible for much of the gravitational lensing observed in the universe.

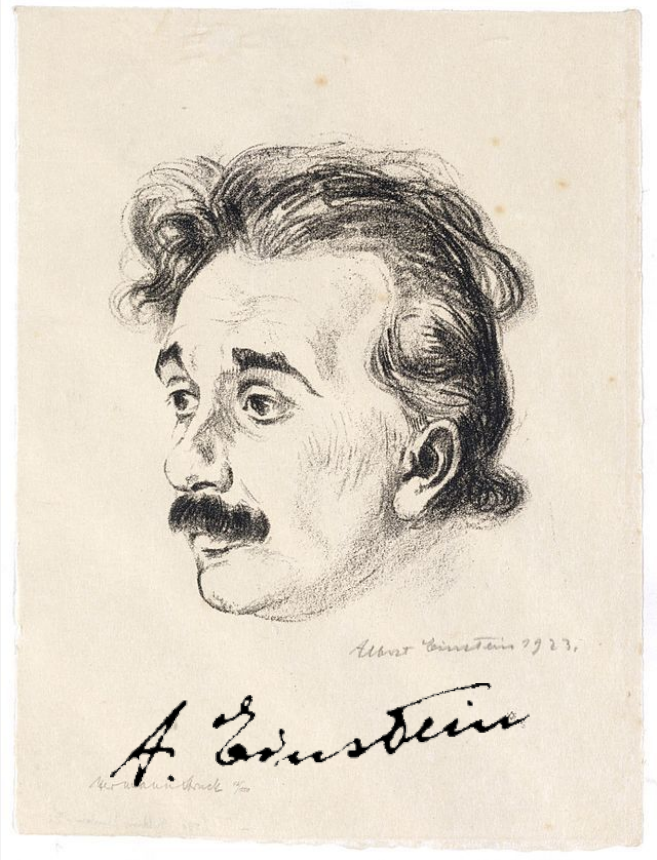


**Einstein Cross: 4 images of the same celestial object, produced by a gravitational lens**





**Faraday delivering a Christmas Lecture at the Royal Institution in 1856**

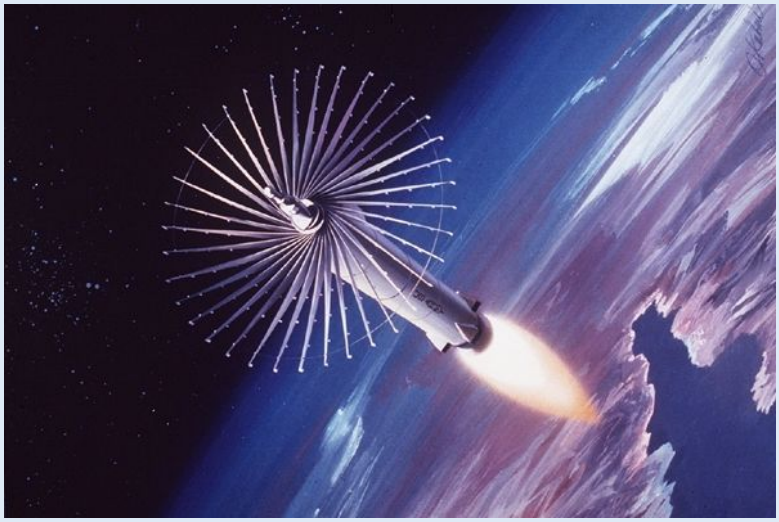


## Supergiants

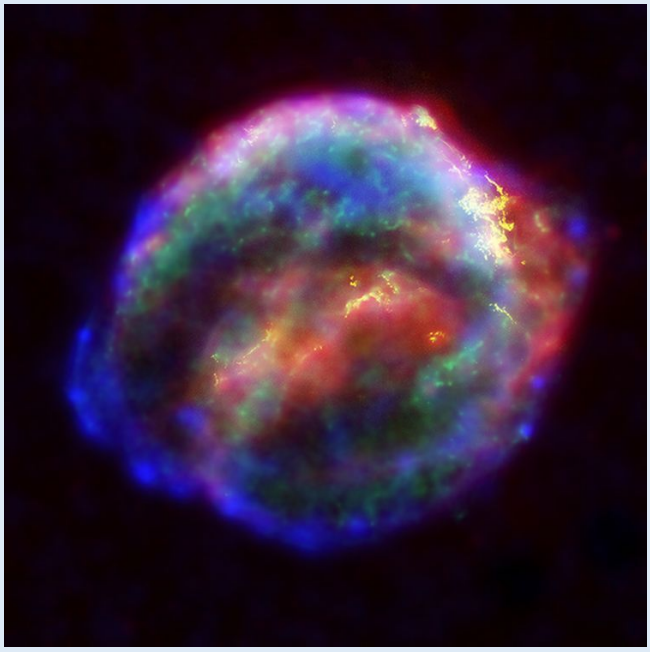
A class of stars that are much larger and more luminous than main-sequence stars of the same temperature and composition.

## ✓ Anti-satellite weapons

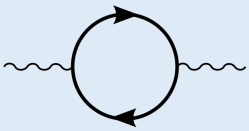
Space weapons specifically designed to disable, incapacitate, or destroy satellites, either for strategic or tactical purposes.



An artistic depiction of a **futuristic anti-satellite weapon** capable of destroying satellites using its "circular saw" extensions.



**Kepler's Supernova Remnant:** Composite of X-ray, Optical, and Infrared Data



✓ **Supernovae** are extremely powerful explosions that occur when a star runs out of fuel and can no longer generate enough pressure to counteract the force of gravity. As a result, the star collapses in on itself, releasing a huge amount of energy in the process. **Supernovae** can be categorized into **Type I** and **Type II**.

- **Type I supernovae** occur in binary star systems where one star has evolved into a **white dwarf**, a compact and extremely dense star that is no longer capable of sustaining nuclear fusion. The white dwarf draws material from its **companion star**, increasing its mass until it reaches a critical point and explodes.

- **Type II supernovae** occur in single massive stars that have exhausted the fuel in their cores and can no longer generate the pressure needed to counteract gravity. As a result, the core collapses in on itself, releasing a huge amount of energy and creating a shockwave that propels the outer layers of the star into space.

**Supernovae** have a profound impact on the universe and the stars and galaxies around them. They release huge amounts of energy, heavy elements, and **cosmic rays** into the **interstellar medium**, which can then be incorporated into new stars and planets. They also play a crucial role in the evolution of galaxies by triggering the formation of new generations of stars and shaping the distribution of elements in the universe. To sum up, **supernovae** are an important aspect of the life cycles of stars and the evolution of the universe. They are powerful explosions that release large amounts of energy and heavy elements into the interstellar medium, and they play a crucial role in the creation of new stars and the shaping of galaxies. Despite their rarity, they are a fascinating subject of study for astronomers and a reminder of the incredible forces at work in the universe.

## Cepheids

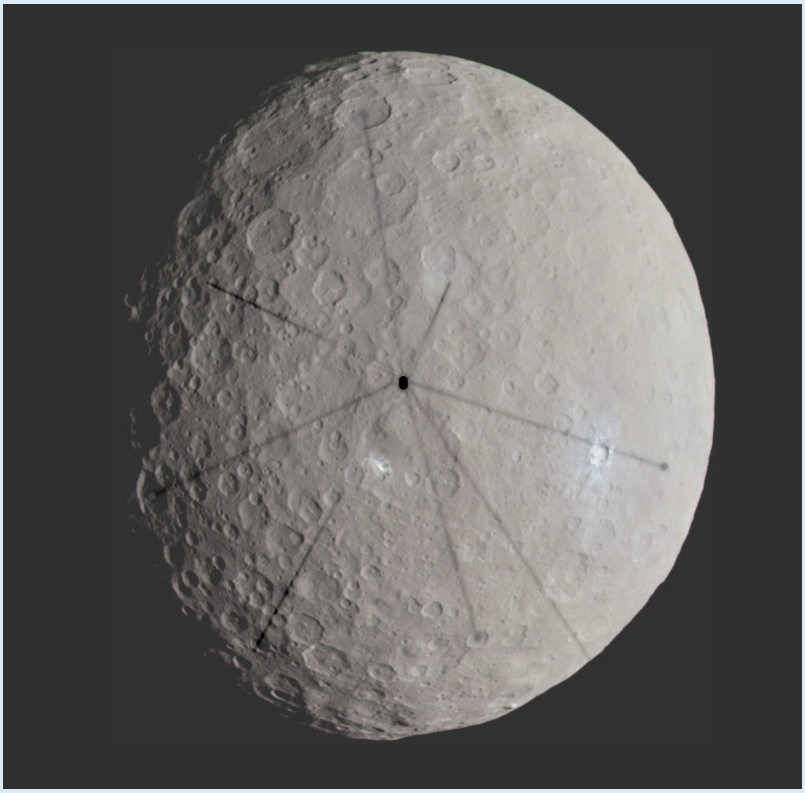
Also known as **Cepheid Variables**, are stars that undergo regular cycles of brightening and dimming. This distinctive behaviour makes them valuable cosmic benchmarks, enabling astronomers to measure distances up to several tens of millions of light-years away.

## Biosatellite

A specially designed artificial satellite intended to transport plants or animals into outer space. Its primary purpose is to conduct research on the impact of space conditions, such as cosmic radiation and weightlessness, on biological organisms while in orbit around celestial bodies.

## Gravity train

A concept proposed for transportation between two points on the surface of a sphere. It involves a direct tunnel connecting the two points passing through the interior of the sphere, enabling commuters to move between the two points by utilizing gravity as the propelling force.



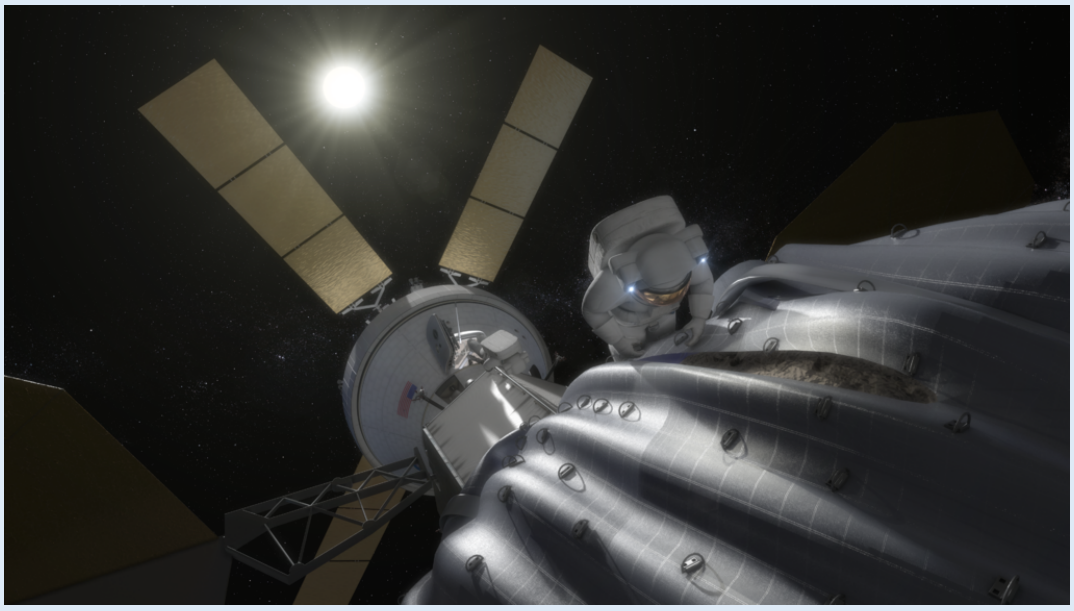
**Ceres gravity train concept**, a theoretical proposal for a transportation system on the dwarf planet Ceres. It envisions a direct tunnel connecting two points on Ceres' surface through its interior. By utilizing the planet's low gravity, commuters could travel along this tunnel without the need for traditional propulsion methods, making it a potentially efficient and unique means of transportation on the celestial body.

## ✓ Orbital ring

A theoretical concept involving the construction of an artificial ring around a celestial body. This ring would be set into rotation at a specific speed, generating a centrifugal force that precisely balances the force of gravity, thereby allowing objects or habitats placed on the ring to remain in a stable, near-weightless state while in orbit.



**Ceres orbital ring concept**, a theoretical proposal involving the construction of an artificial ring around the dwarf planet **Ceres**. This ring would be set into rotation at a specific speed, generating a centrifugal force that would precisely counteract the force of gravity on the ring and any objects attached to it.



In this visualization, we see an **astronaut** preparing to collect samples from a **captured asteroid**, which has been safely positioned within a stable orbit in the Earth-moon system. The asteroid capture bag is equipped with numerous rings, enabling the astronaut to navigate with precision and caution while exploring the asteroid's surface.

## Potentially hazardous object

A near-Earth object, such as an asteroid or comet, follows a path that allows it to come close to Earth, making close approaches possible. It is of substantial size, capable of causing significant damage if it were to collide with our planet.

## Earth-grazing fireball

Imagine a **meteoroid**, a diminutive rocky or metallic object flying through space. Sometimes, these objects enter the Earth's atmosphere. When they do, they usually burn up and disappear before reaching the ground. However, in rare cases, some objects come in at a special angle that allows them to skim through the top part of the atmosphere without completely burning up. When this happens, it creates a spectacular sight called an **"Earth-grazing fireball."** It's like a bright, glowing ball of light that travels across the sky for an extended duration before finally departing the atmosphere. It's a pretty amazing event to witness!



Frederic Edwin Church's painting **"The Meteor of 1860"** depicting the fascinating sight of an Earth-grazing meteor procession.

## ✓ Global catastrophic risk

Also known as doomsday scenario, is a theoretical and potential future event that could cause widespread damage to human well-being or even the extinction of humanity.



The **Barringer Meteorite Crater**, located in Flagstaff, Arizona, exhibits clear indications of the impact of celestial objects on Earth.



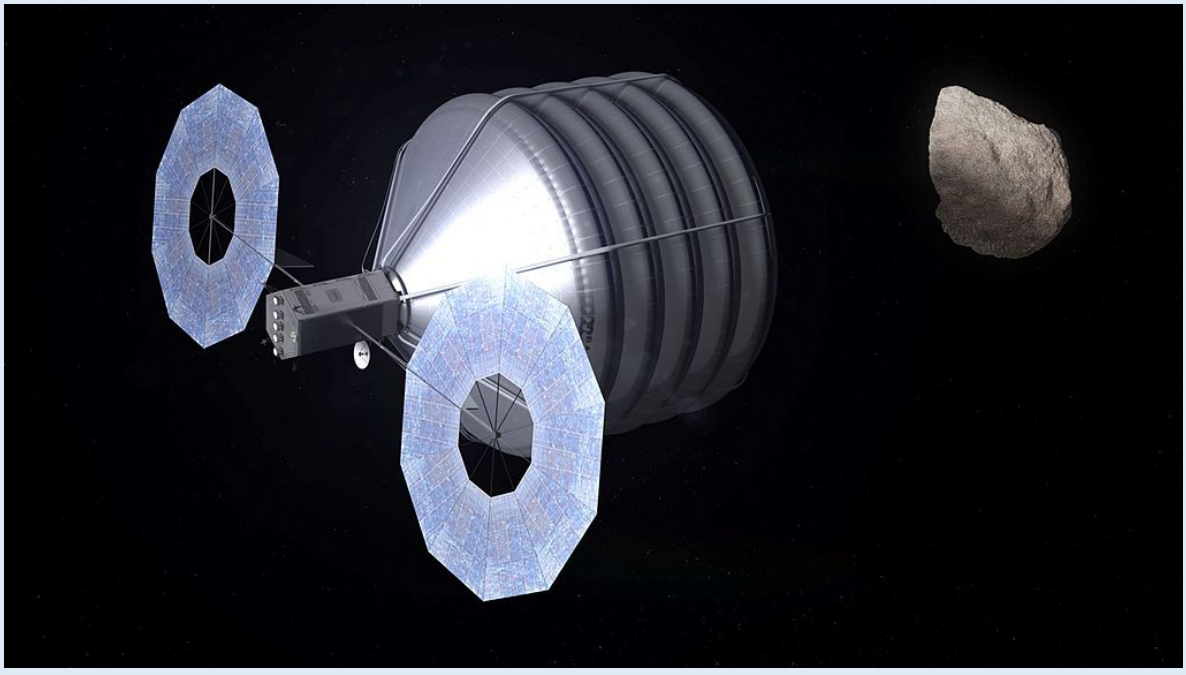
✓ **The first spider web built in space during the Skylab 3 mission in 1973.**

## Asteroidal water

Water that is found on or within **asteroids**, which are small rocky celestial bodies that orbit the Sun. Some **asteroids** contain water in the form of **ice** or **hydrated minerals**, making them potential sources of water for future space exploration missions or for supporting human settlements beyond Earth. Studying and understanding the presence of water on asteroids is of significant interest to scientists and space agencies for potential resource utilization and sustaining future space activities.

## Asteroid impact prediction

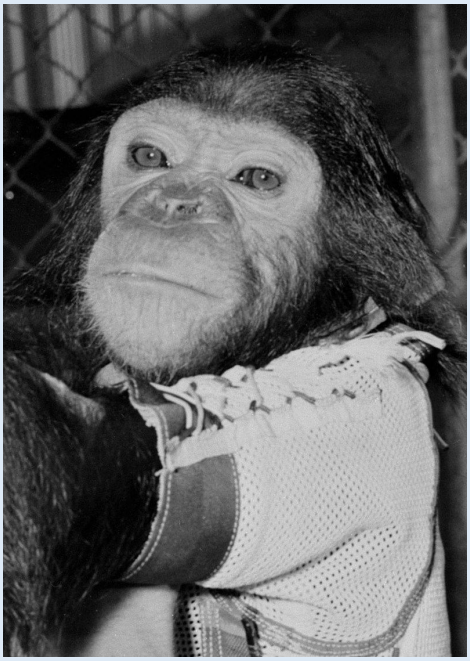
Forecasting the dates and times when asteroids might collide with Earth, as well as predicting the locations and potential severities of such impacts. This is crucial for understanding and mitigating the potential risks posed by **near-Earth asteroids** and developing strategies to protect our planet from potential catastrophic events.



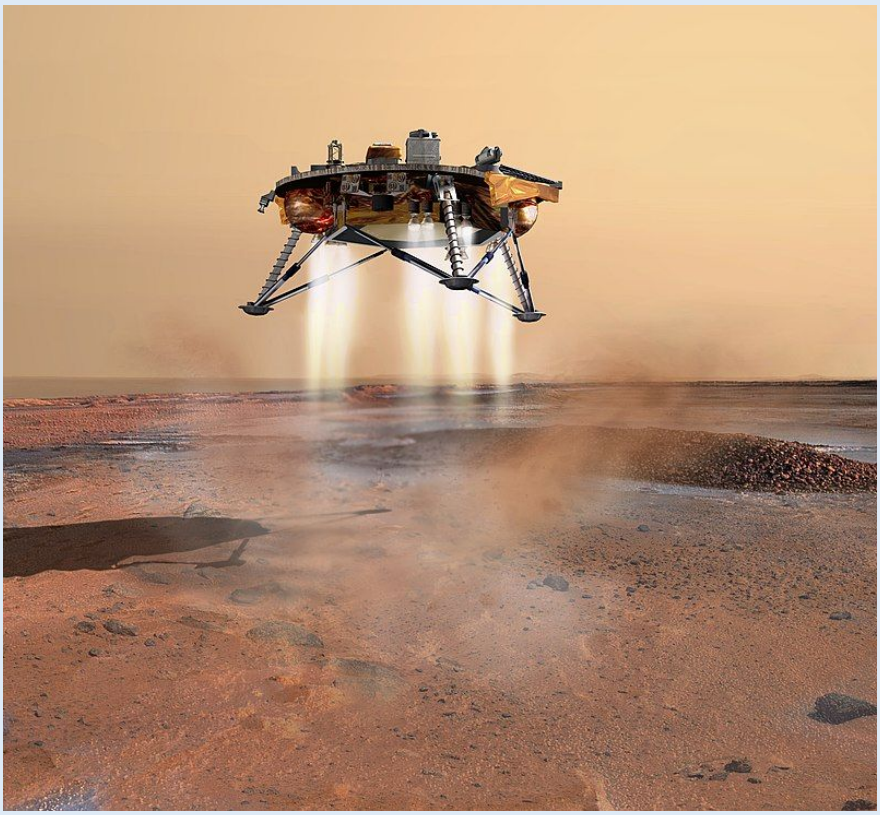
An artistic depiction of Asteroid Capture in Progress showcases an ongoing process of capturing an asteroid for scientific study, resource extraction, or planetary defence purposes.



In 1994, while on a mission aboard the **Space Shuttle Columbia**, astronaut **Donald Thomas** is seen examining a **newt** (a small amphibian belonging to the salamander family).



On November 29, 1961, during the **NASA Mercury-Atlas 5 flight**, a chimpanzee named **Enos** accomplished a remarkable milestone by becoming the only chimpanzee and the third primate to orbit the Earth. This milestone was a significant step in preparing for **human spaceflight**, as it provided valuable data on the effects of space travel on living organisms before sending astronauts into space.



Artistic depiction of the **NASA Phoenix spacecraft** as it lands on the surface of Mars.

## Quantum field theory

A **theoretical framework in physics** that combines **classical field theory** and **quantum mechanics** with **special relativity** to describe the behaviour of subatomic particles and their interactions. It provides a powerful and comprehensive understanding of the fundamental forces and particles that govern the microscopic world, making it a cornerstone of modern theoretical physics.

## Relativistic quantum mechanics

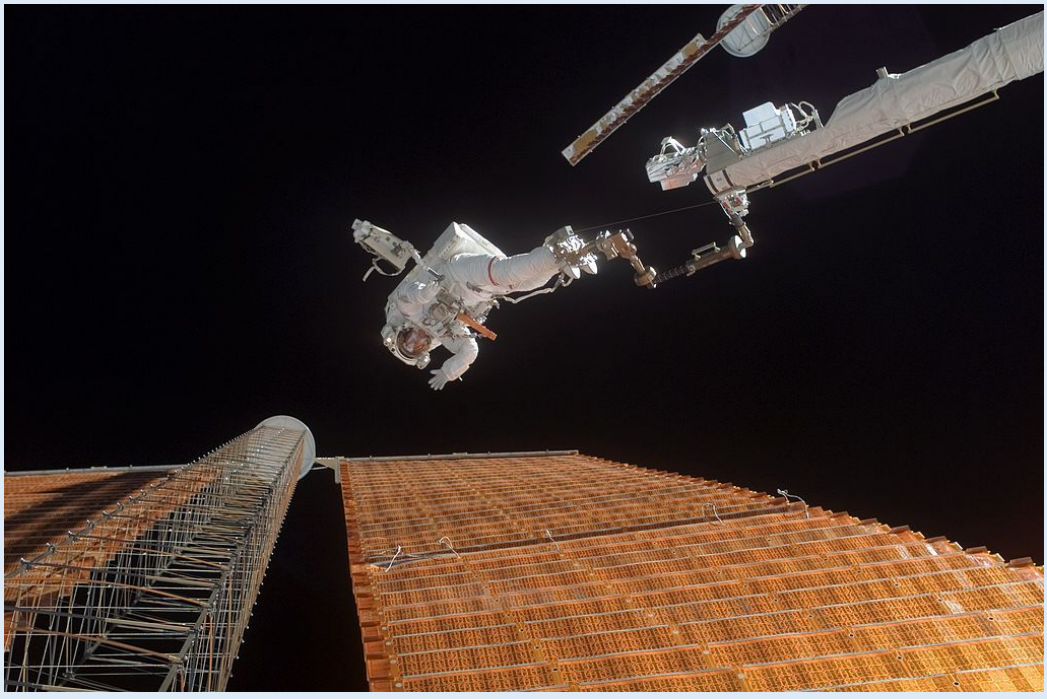
A branch of **theoretical physics** that combines the principles of **quantum mechanics** and **special relativity** to describe the behaviour of subatomic particles, particularly those moving at speeds close to the speed of light.

## Gravity tractor

A conceptual spacecraft designed to alter the trajectory of a celestial object in space, often an asteroid posing a potential threat to Earth, without physically contacting it and instead transmitting the required impulse through its gravitational field.

## Extraterrestrial liquid water

Water in its liquid state existing beyond Earth's boundaries. It is a topic of great interest since it has captured significant attention due to its vital role as a fundamental requirement for the life forms we are familiar with, thereby being considered a crucial factor for the potential existence of life beyond our planet.



A 7-hour, 19-minute spacewalk was undertaken by astronaut **Scott Parazynski** during the **STS-120 mission**. His objective during this spacewalk was to repair a damaged solar panel that contributes to the power supply of the **International Space Station**.

## Stellar dynamics

The study and analysis of the motion, interactions, and behaviour of stars within galaxies or star clusters. This branch of astrophysics plays a crucial role in understanding the evolution, structure, and overall dynamics of galaxies and star systems.

## Corrosion in space

The **corrosion of materials** when exposed to the conditions of outer space. Unlike **conventional corrosion** driven by moisture and oxygen, **outer space corrosion** results from factors like vacuum conditions, intense exposure to ultraviolet and X-ray radiation, and the impact of energetic charged particles such as electrons and protons originating from solar wind.



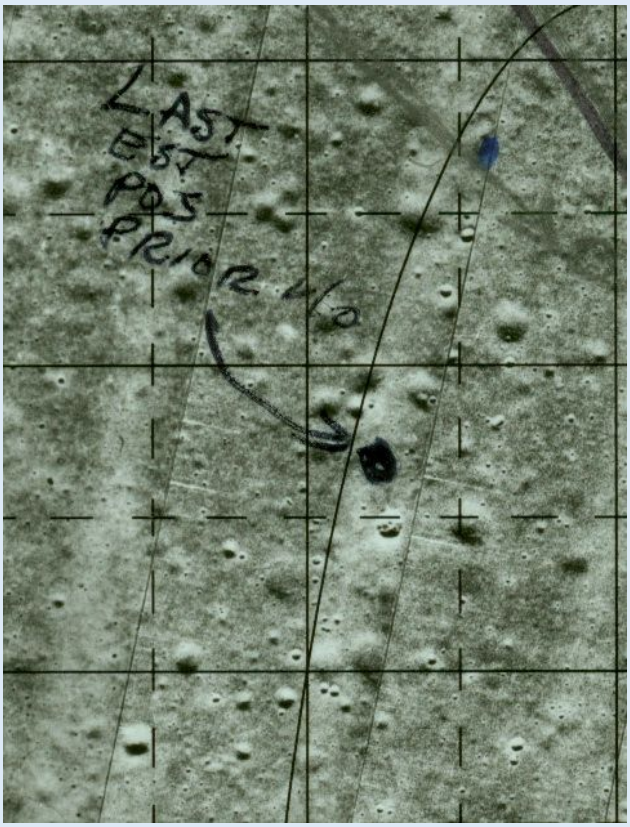
## Astronautical hygiene

The practices and protocols followed by astronauts to maintain cleanliness, personal health, and prevent the spread of germs and diseases in the challenging environment of space.

## Space Pen

Also recognized as the **Zero Gravity Pen**, is a specially designed pen that has gained popularity for its ability to write in various challenging conditions, including zero gravity, underwater, on damp and oily surfaces, at various angles, and in a very wide range of temperatures.






An astronaut named **Michael Collins** annotated a partial map of the Moon's surface while in lunar orbit, adding notations that included **"Last Est Pos Prior L/O."** This notation indicated the estimated location of the lander.

## Space-based radar

A radar deployed in space for gathering space-related information. It is a powerful tool that can be used to map the Earth's surface, track objects in space, and monitor weather patterns.

## Astrobiology

A multidisciplinary field of study that seeks to understand the origin, evolution, and distribution of life in the universe. It combines the knowledge and methods from astronomy, biology, chemistry, geology, and other sciences to answer questions about life in the universe.

## Astrochemistry

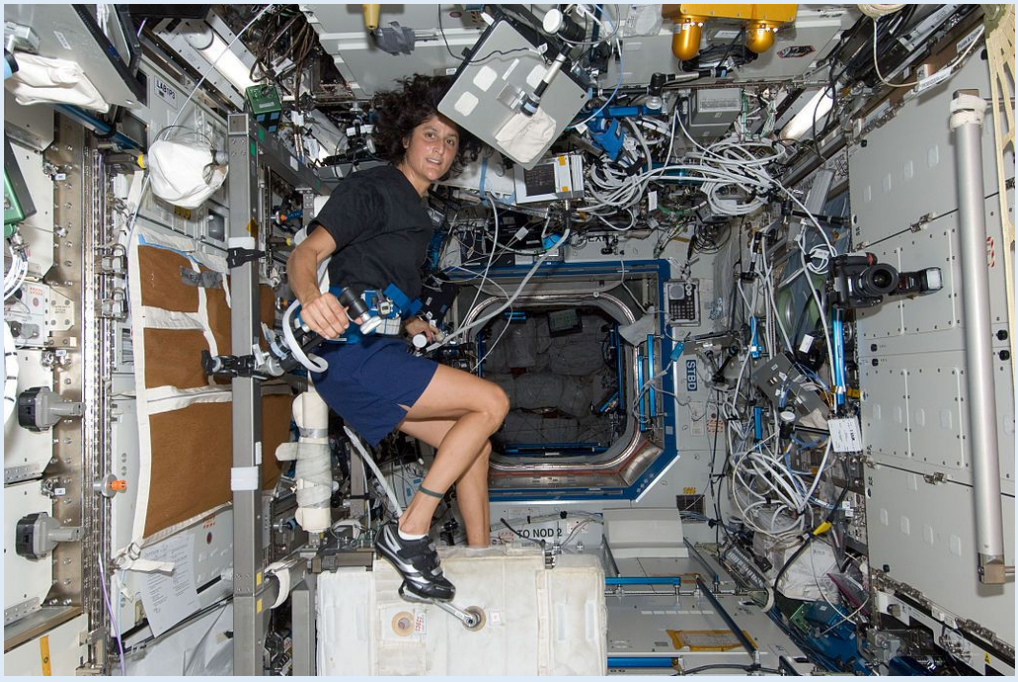
The study of the chemical composition and processes in astronomical objects, including stars, planets, moons, comets, asteroids, and interstellar and intergalactic environments. It is an interdisciplinary field that combines chemistry, physics, and astronomy to understand the formation and evolution of these objects.



The **Aurora Australis** as seen from the **Space Shuttle Discovery** during the **STS-39 mission** in **May 1991**.

## Space nursing

A **specialized field within nursing** that focuses on the unique medical and healthcare needs of astronauts during space missions and conducts research into the physiological impacts of space travel on the human body. It plays a crucial role in ensuring the health and well-being of astronauts before, during, and after their spaceflights.



In the **Destiny laboratory** of the **International Space Station**, NASA astronaut **Sunita Williams**, who served as **Expedition 32 flight engineer**, engages in exercise using the **Cycle Ergometer with Vibration Isolation System** (CEVIS).

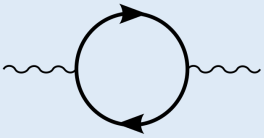


In her leisure moments, **NASA** astronaut **Cady Coleman**, an Expedition 27 flight engineer, enjoys playing a flute inside the **JAXA Kibo laboratory** situated on the **International Space Station**.

## The pulsating Universe theory

A **cosmological model** that proposes that the universe undergoes cycles of expansion and contraction, with periods of rapid expansion followed by periods of contraction. According to this model:

1. The universe is expanding, but it will eventually slow down and reverse.
2. The universe will eventually contract to a very small size.
3. The universe will then expand again, starting a new cycle.
4. The cycles of expansion and contraction go on forever.





During December 2009, the crew of the **International Space Station** (ISS) was spotted wearing cheerful Christmas hats while inside the **Zvezda service module**.

## ✓ Nuclear Fusion

$$\text{Nuclei } (M_1) + \text{Nuclei } (M_2) \rightarrow \text{Larger Nuclei } (M_3 < M_1 + M_2) + \text{heat (and light energy)}$$




Christa McAuliffe



Judith A. Resnik

In the tragic incident of January 28, 1986, **Christa McAuliffe** and **Judith A. Resnik**, along with the rest of the **STS-51-L crew**, lost their lives in the **Challenger disaster**.



**Kalpana Chawla**



**Laurel Clark**

In the **Columbia disaster** on February 1, 2003, **Kalpana Chawla** and **Laurel Clark**, along with all members of the **STS-107 crew**, tragically lost their lives.

✔ A **Plasmon** is a quantized electro-magnetic wave propagating in dense dielectric plasma. It behaves like a relativistic Bose particle with energy = $\hbar w_p$ where wp is the Plasmon frequency.

**energetically unstable**

Plasmon ⟶ neutrino-antineutrino pair

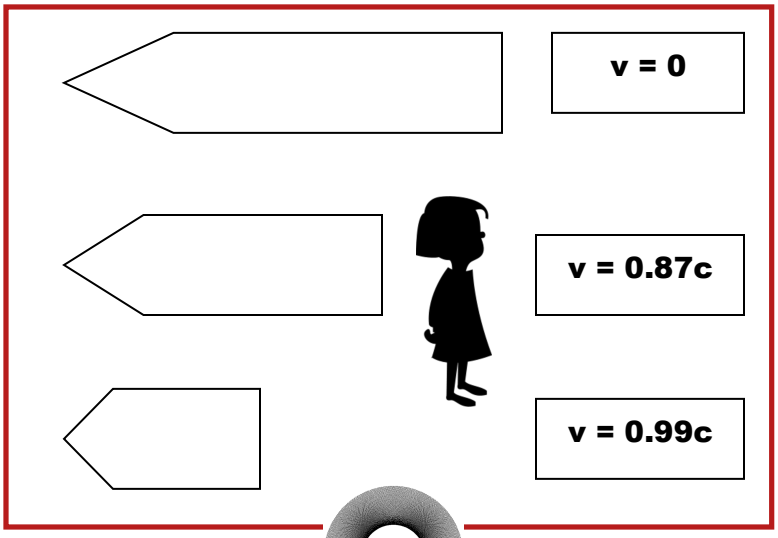
"A world where only a tiny super-elite are capable of understanding advanced science and technology and its applications would be, to my mind, a dangerous and limited one. I seriously doubt whether long-range beneficial projects such as cleaning up the oceans or curing diseases in the developing world would be given priority. Worse, we could find that technology is used against us and that we might have no power to stop it. I don't believe in boundaries, either for what we can do in our personal lives or for what life and intelligence can accomplish in our universe. We stand at a threshold of important discoveries in all areas of science. Without doubt, our world will change enormously in the next fifty years. We will find out what happened at the Big Bang. We will come to understand how life began on Earth. We may even discover whether life exists elsewhere in the universe. While the chances of communicating with an intelligent extra-terrestrial species may be slim, the importance of such a discovery means we must not give up trying. We will continue to explore our cosmic habitat, sending robots and humans into space. We cannot continue to look inwards at ourselves on a small and increasingly polluted and overcrowded planet. Through scientific endeavour and technological innovation, we must look outwards to the wider universe, while also striving to fix the problems on Earth. And I am optimistic that we will ultimately create viable habitats for the human race on other planets. We will transcend the Earth and learn to exist in space. This is not the end of the story, but just the beginning of what I hope will be billions of years of life flourishing in the cosmos. And one final point—we never really know where the next great scientific discovery will come from, nor who will make it. Opening up the thrill and wonder of scientific discovery, creating innovative and accessible ways to reach out to the widest young audience possible, greatly increases the chances of finding and inspiring the new Einstein. Wherever she might be. So remember to look up at the stars and not down at your feet. Try to make sense of what you see and wonder about what makes the universe exist. Be curious. And however difficult life may seem, there is always something you can do and succeed at. It matters that you don't just give up. Unleash your imagination. Shape the future."

**Stephen Hawking, Brief Answers to the Big Questions**



**This is how the length of a spaceship changes at different speeds.**

**According to theory of relativity:**




When you sit with a nice girl for two hours you think it's only a minute. But when you sit on a hot stove for a minute you think it's two hours. That's relativity.

**–Albert Einstein**

For massive stars:

$$\text{Luminosity} \propto (\text{mass})^4$$

$$\text{Luminosity} = \text{solar luminosity} \times \frac{(\text{mass})^4}{(\text{solar mass})^4}$$

while for less massive stars:

$$\text{Luminosity} \propto (\text{mass})^3$$

$$\text{Luminosity} = \text{solar luminosity} \times \frac{(\text{mass})^3}{(\text{solar mass})^3}$$

✓ **Mechanics**

- Motion
- Forces
- Energy

| | |
|---|---|
| **Kinematics** | The science of describing the motion of objects |
| **Dynamics** | The science of describing the motion of objects under the action of forces |
| **Statics** | The branch of mechanics dealing with objects at rest or in equilibrium |

✓ **Energetics**

**A branch of mechanics that deals primarily with energy and its transformations**

Who would set a limit to the mind?
Who would dare assert that we
know all there is to be known?

**– Galileo Galilei**

✓ **Motion**

- **Translational motion:** Motion that results in a change of location
- **Oscillatory motion:** To and fro motion of the object about its fixed position
- **Rotational motion:** Motion that occurs when an object spins
- **Random motion:** Kind of motion where an object moves in any direction and the direction keeps changing continuously

$v = \frac{dx}{dt}$ How fast object moves

$\omega = \frac{d\theta}{dt}$ How fast object spins

✓ **Translatory motion**

- **Rectilinear motion:** motion in a straight line
- **Curvilinear motion:** motion in a curved path

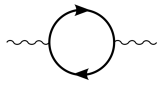
- **Uniform motion:** The motion of a object along a straight line with steady speed

  { Zero acceleration }
- **Non-Uniform motion:** The motion of a object along a straight line with variable speed

  { Non-Zero acceleration }

**Chaos** Complete disorder and confusion

**Quantum mechanics is not chaotic – but probabilistic.**



**The correspondence principle**

Classical mechanics is the classical limit of quantum mechanics

**Chaos Theory**

{ The principles and mathematical operations }

↓

Deal with **nonlinear** things that are effectively impossible to predict or control, like turbulence, weather, the stock market, our brain states, and so on.

**Classical probability** is a simple form of probability that has equal odds of something happening.

**Quantum chaos is a branch of physics which is concerned with establishing the relation between chaotic systems quantum systems.**

**✓ Quantum mechanics**

A fundamental theory of the mechanics of atoms, molecules and other physical systems that are subject to the **Heisenberg uncertainty principle** or indeterminacy principle



**Speed** = $\frac{\text{Distance}}{\text{time}}$

- Speed $\propto$ distance when time is constant
- Speed $\propto \frac{1}{\text{time}}$ when distance is constant

I still struggle with the same problems as ten years ago. I succeed in small matters but the real goal remains unattainable, even though it sometimes seems palpably close. It is hard, yet rewarding: hard because the goal is beyond my abilities, but rewarding because it makes one oblivious to the distractions of everyday life.

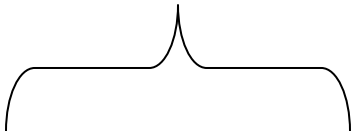


**Albert Einstein**

**Synthetic geometry**

The geometry that uses logic to test proofs

**Analytic geometry**



Algebraic symbolism and methods are used to represent and solve problems in geometry

**✓ Elasticity**

Ability of a deformed body to return to its original shape and size when the forces causing the deformation are removed

**✓ Hooke's Law**

The force needed to extend or compress a spring by some distance is proportional to that distance

**✓ Buoyancy**

**The force exerted on an object immersed in a fluid**

**Magnetic Force**

The attraction or repulsion between charged bodies in motion

**Inertia is the resistance to change in velocity**

✓ Weight = Buoyancy

↓

**A person floats in still water**

- acceleration $\propto$ net force when mass is constant
- acceleration $\propto \frac{1}{\text{mass}}$ when net force is constant

Momentum = mass × velocity

**Force = mass × acceleration**

Yank = mass × jerk

**jerk** is the rate at which an object's acceleration changes with respect to time

Tug = mass × snap

**snap** is the rate of change of jerk with respect to time

Snatch = mass × crackle

**crackle** is the rate of change of snap with respect to time

Shake = mass × pop

**pop** is the rate of change of **crackle** with respect to time

**Kinetic energy**

The energy associated with motion

**Potential energy**

The energy associated with position

✓ **Mass is a measure of resistance to acceleration**

- When a system does work on its surroundings: the total energy of the system decreases. Work is done by the system.
- When the surroundings does work on a system: the total energy of the system increases. Work is done on the system.

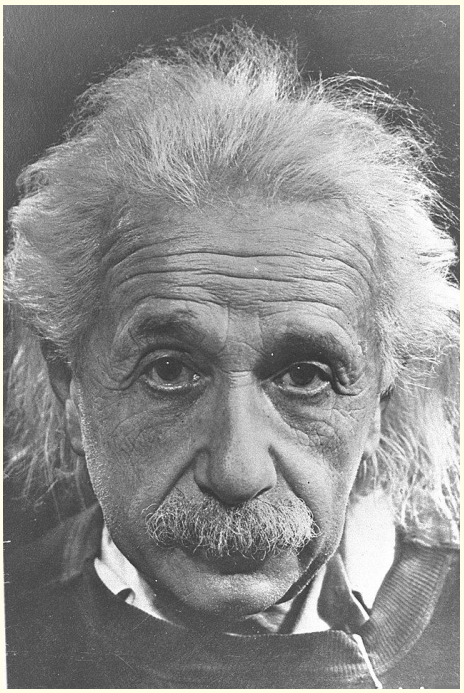


What you learn from a life in science is the vastness of our ignorance.

**– David Eagleman**

| | |
|---|---|
| **Photons** | quanta of the electromagnetic field |
| **Gluons** | quanta of the strong interaction field |
| **Intermediate bosons** | quanta of the weak force field |

| | **Force** | **Potential Energy** |
|---|---|---|
| **Gravity near the earth's surface** | $mg$ | $mgh$ |
| **Gravity between particles** | $\frac{GMm}{r^2}$ | $\frac{GMm}{r}$ |
| **Electric Charge** | $\frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$ | $\frac{q_1 q_2}{4\pi\varepsilon_0 r}$ |
| **Electric Field** | $qE$ | $qV$ |
| **Ideal Spring** | $-kx$ | $\frac{1}{2}kx^2$ |
| **Friction** | $-\mu N$ | |






A. Einstein



A public lecture about a **model solar system** with a lamp illuminating the faces of the audience sounds like a creative and engaging way to teach people about the **solar system and astronomy**.

## ✓ Clockwork universe

In the history of science, the universe has been compared to a mechanical clock. It keeps on ticking as a perfect machine, with its gears regulated by the principles of physics, keeping every component of the machine deterministic.

## ✓ Clearing the neighbourhood

Also known as **achieving dynamical dominance** around the orbit of a celestial body refers to the scenario where the celestial body's gravitational influence becomes strong enough to establish its dominance, resulting in the absence of other celestial bodies of similar size except for its own natural satellites or the ones that are significantly influenced by its gravity.

## ✓ Satellite collision

The scenario where two artificial satellites in Earth's orbit collide with each other. Such collisions can have significant implications for space operations, satellite functionality, and the generation of space debris.

## ✓ Laser broom

An envisioned terrestrial laser-powered propulsion system designed to clear space debris from the trajectory of artificial satellites, including the International Space Station, aiming to avert any inadvertent harm to space equipment.



✓ **Artistic depiction of the Laser broom.**

Broadly speaking, white dwarfs are the dying members of stars that have ceased their nuclear fusion processes. They are compact and therefore very dense. This leads to degeneracy pressure, a phenomenon arising from quantum mechanical principles. It is this degeneracy pressure which prevents the total collapse of the dead star and gives it a finite radius. Unlike gas pressure, degeneracy pressure can exist even at absolute zero of temperature.

For **non-relativistic particles** (particles with speeds much lower than the speed of light), the **degeneracy pressure** ($P_{deg}$) **in a white dwarf** is proportional to the density raised to the power of 5/3.

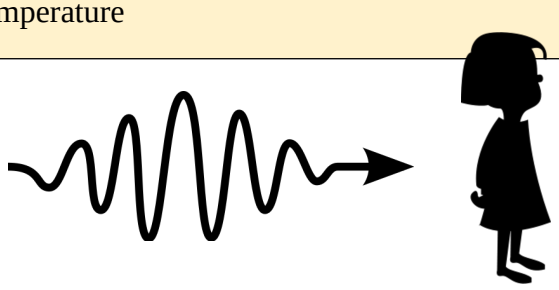
$$P_{deg} \propto \rho^{5/3}$$

where $\rho$ is the density of the white dwarf. In the **relativistic case**, where the speeds of particles approach the speed of light, the equation for degeneracy pressure ($P_{deg}$) in a white dwarf is modified to include relativistic effects. The degeneracy pressure is proportional to the density raised to the power of 4/3.

$$P_{deg} \propto \rho^{4/3}$$

✓ $P_{deg}$

- Increases as the density of the white dwarf increases (meaning more mass is packed into a smaller volume).
- Independent of temperature



✓ **Pulsars are nothing but rotating neutron stars**

- The size of each is around 10 km
- The rotational period of a pulsar is comparable with that of a neutron star
- They both result from supernova explosions

**There is a mass limit to neutron stars.** It is approximately about 2 to 3 times the mass of our Sun, commonly referred to as the **Tolman-Oppenheimer-Volkoff** (TOV) **limit**. Beyond this limit the degenerate neutron pressure will not be sufficient to overcome the gravitational contraction and the star collapses. This collapse could result in the formation of a **black hole** or other exotic phenomena, depending on the precise conditions and dynamics involved. **For example,** if the neutron star has a very strong magnetic field, it could collapse into a **magnetar**, which is a type of neutron star with an incredibly powerful magnetic field, billions of times stronger than that of typical neutron stars.



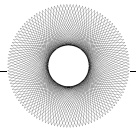
**Electromagnetic wave consists of an oscillating electric field with a perpendicular oscillating magnetic field.**

## Gravitons + Bosons

have been hypothesized but never observed experimentally.



**Hydrogen** (H) and **helium** (He) were found in large quantities in the early Universe while all elements up to iron (Fe) were synthesized in stars and other elements were born in the explosive deaths of massive stars (M > 1.4 **solar masses**).



Electron —charge inversion→ antielectron

## Opposite electric charges attract



via exchange of virtual photons

## Same electric charges repel



via exchange of virtual photons

## ✓ Operation Burnt Frost

A military mission designed to intercept and eliminate a non-operational **U.S. National Reconnaissance Office** (NRO) satellite named **USA-193**.



Launch of the **SM-3 missile** that intercepted **USA-193** on February 20, 2008.



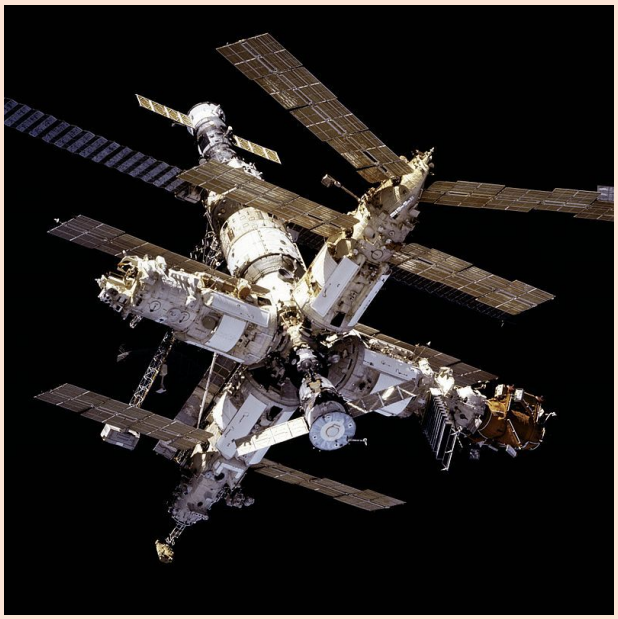
**Vanguard 1**, launched on March 17, 1958, is the oldest artificial satellite still in orbit around Earth. It is expected to remain in orbit for another 240 years, until it is pulled into the atmosphere and burns up.

## ✓ Graveyard orbit

Also known as a **"disposal orbit"** or **"junk orbit",** is a specific region in space where dysfunctional or non-operational satellites, expended rocket stages, and other space debris are intentionally placed to reduce the risk of collision with active satellites and spacecraft in operational orbits such as geosynchronous orbit or geostationary orbit.

## ✓ Spacecraft cemetery

Also referred to as the **South Pacific Ocean Uninhabited Area** (SPOUA), is a specific remote region located in the **southern Pacific Ocean**, where fragments of malfunctioning satellites and discarded spacecraft are intentionally allowed to sink to the bottom of the ocean. This area has become a repository for dysfunctional space hardware, serving as a final resting place for these no-longer-operational objects.



**Mir**, a space station operated by the **Soviet Union**, was eventually placed into the **Spacecraft Cemetery** in 2001.

✓ The **Compton Effect**, also known as **Compton scattering**, is a phenomenon in which a photon collides with an electron, transferring some of its energy to the electron and causing it to recoil. This effect was first observed by **Arthur Compton** in 1923 and is an important concept in quantum mechanics and particle physics. The mathematical formula for the **Compton Effect** is given by:

$$\lambda' - \lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

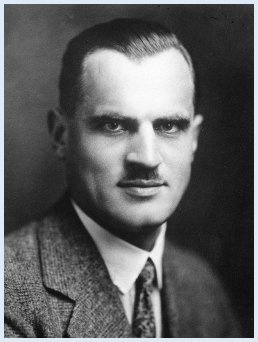
where $\lambda$ is the wavelength of the incident photon, $\lambda'$ is the wavelength of the scattered photon, h is Planck's constant, $m_e$ is the rest mass of the electron, c is the speed of light, and $\theta$ is the angle between the direction of the incident photon and the direction of the scattered photon. To illustrate this formula, let's consider an example where an **X-ray photon** with a wavelength of 0.1 nm collides with a free electron at rest. After the collision, the photon is scattered at an angle of 30 degrees from its original direction. We can calculate the wavelength of the scattered photon using the **Compton formula**:

$$\lambda' - 0.1\ \text{nm} = \frac{6.62606957 \times 10^{-34}\ \text{Js}}{9.10938291 \times 10^{-31}\ \text{kg} \times 2.99792458 \times 10^{8}\ \text{m/s}} \times (1 - \cos 30^{o})$$

$$\lambda' - 0.1\ \text{nm} = 2.426\,3102389 \times 10^{-12}\ \text{m} \times 0.84574855011$$

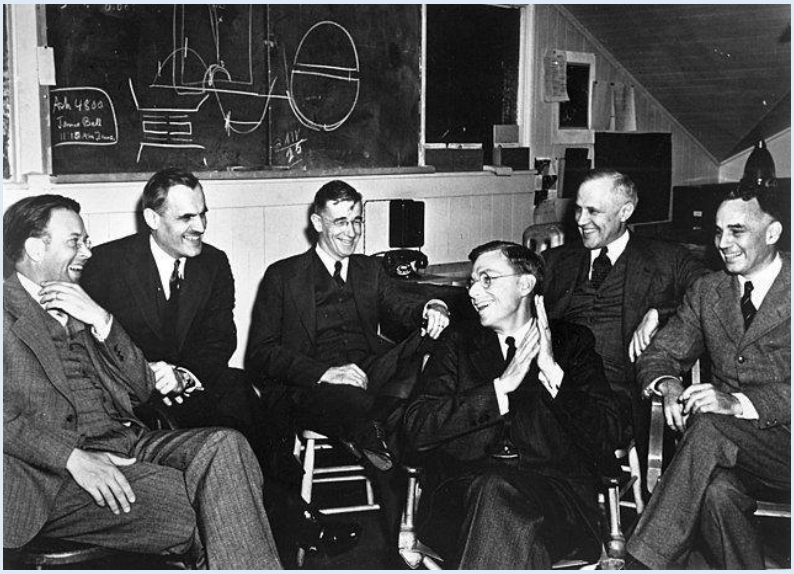
$$\lambda' - 0.1\ \text{nm} = 0.00205204836\ \text{nm}$$

$$\lambda' = 0.10205204836\ \text{nm}$$

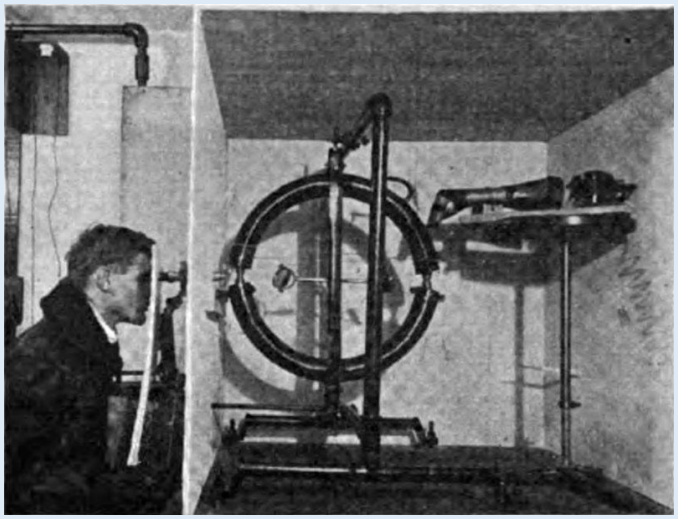


Arthur H. Compton

Therefore, the **scattered photon** has a wavelength of 0.10205204836 nm, which is slightly longer than the wavelength of the incident photon due to the transfer of energy to the electron. This increase in wavelength is known as the **Compton shift**, and its magnitude depends on the angle of scattering and the energy of the incident photon. This formula is a fundamental equation in **quantum mechanics** and is used in a variety of fields, including medical imaging, materials science, and particle physics.



A meeting regarding the **184-inch cyclotron project**, held at the University of California, Berkeley, on March 29, 1940. **Left to right:** Ernest O. Lawrence, Arthur H. Compton, Vannevar Bush, James B. Conant, Karl T. Compton, and Alfred L. Loomis.

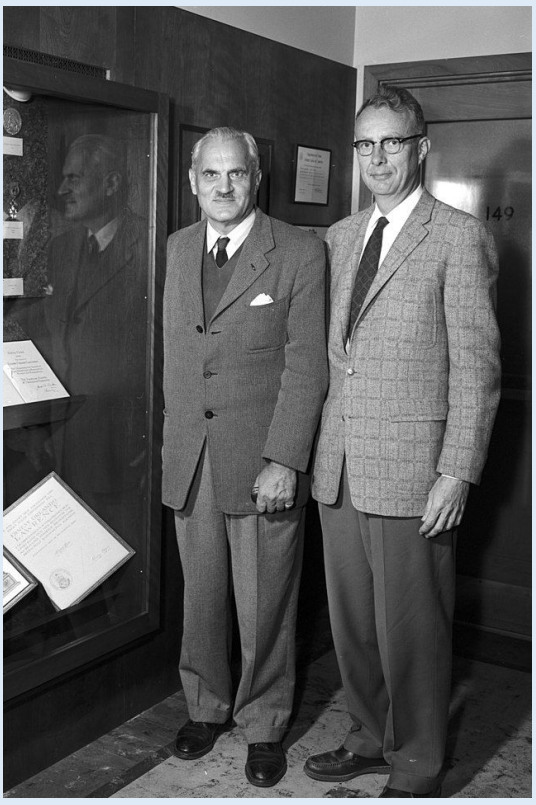


**Arthur Compton** watching the earth revolve by the **Compton Tube**.

A scientific apparatus that is used to demonstrate the Earth's rotation



**Arthur Compton** (left), the director of the Metallurgical Project, at Oak Ridge, with **Martin D. Whitaker** (right), the director of the Clinton Laboratories.



1958 photograph of physicists Arthur Compton and Luis Walter Alvarez, taken by Donald Cooksey.



**Donald Cooksey** was an American physicist who was the associate director of the Lawrence Radiation Laboratory of the University of California at Berkeley. He made important contributions to the development of nuclear technology, particularly in the design of the electromagnetic separation process for enriching uranium isotopes. This technology was used in the **Manhattan Project** during **World War II** to produce the first atomic bomb. Cooksey received his undergraduate degree in physics from Pomona College in 1914 and his **Ph.D**. from the **University of California**, Berkeley in 1923. He then went on to work at the university's Radiation Laboratory, where he helped develop the cyclotron, a type of particle accelerator used for nuclear research. During World War II, **Cooksey** played a key role in the **Manhattan Project**, where he helped design the electromagnetic separation process for enriching uranium isotopes. After the war, he returned to the University of California, Berkeley, where he served as the associate director of the Radiation Laboratory. Overall, **Donald Cooksey** was a pioneering physicist who made significant contributions to the field of nuclear technology, and his work helped lay the groundwork for the development of atomic energy.

## Top quark

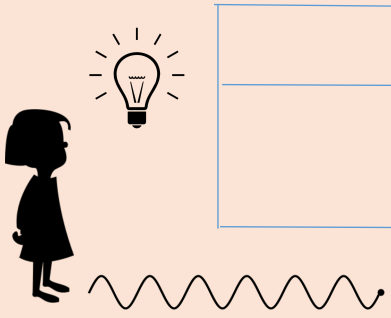
Discovered at the **Fermi National Accelerator Laboratory** in Illinois in 1995, also referred to as the **truth quark**, is the most massive of all known fundamental particles and interacts with the **Higgs boson** the most. It is very unstable, and it decays into a bottom quark and a W boson within a fraction of a second.

## ✓ Massless bosons

| Gluon | + | Graviton | + | Photon |
|---|---|---|---|---|
| which is the carrier of the strong force | | which is hypothetical carrier of gravity | | which is the carrier of electromagnetic force |

**Plasma** is a very **good conductor of electricity** due to its abundant free electrons, which are able to move freely, facilitating the transmission of electric current. This characteristic plays a vital role in a wide range of applications, spanning from **fluorescent lighting** and **fusion research** to natural phenomena like **lightning**.

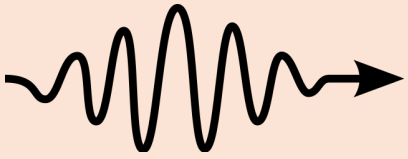
## Proton-proton chain and the CNO cycle fusion processes



- Increase the amount of helium-4
- Reduce the number of protons in the core of the star.



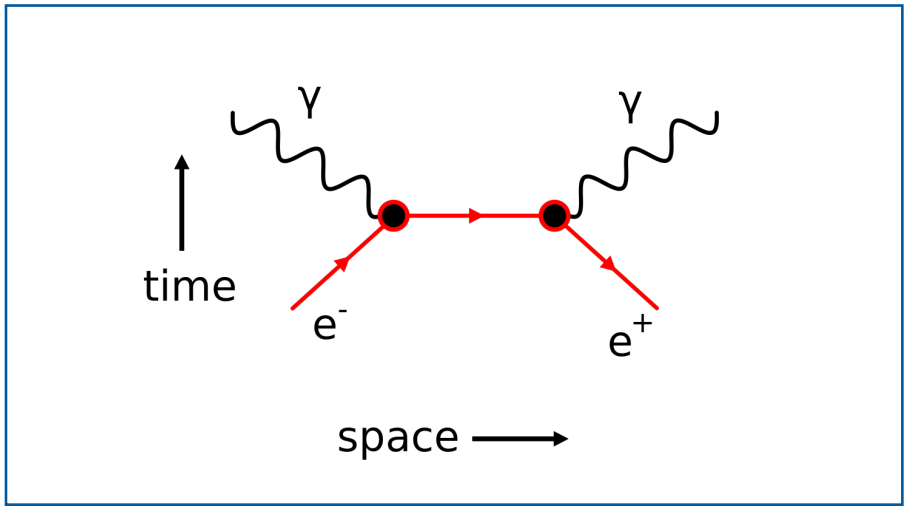
**Lightning**, a highly energetic discharge of electricity, provides an example of **plasma** manifesting at the Earth's surface. Typically, these **lightning discharges** carry around 30 kiloamperes of current with potential differences reaching up to 100 megavolts. This discharge heats the surrounding air rapidly, creating a superhot, ionized state known as **plasma**. This **plasma** radiates a **spectrum of electromagnetic waves** including radio waves, visible light, X-rays, and even gamma rays. In these **lightning events**, plasma temperatures can surge to levels nearing 30,000 Kelvin, and the number density of electrons might surpass $10^{24}$ per cubic meter.



Electromagnetism → combined force of electricity and magnetism.

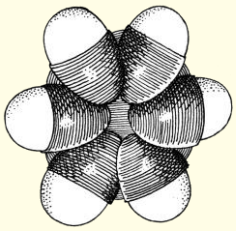
✓ **Low-energy cosmic rays** emitted by the Sun primarily consist of **protons** (constituting 90% of the total) and **helium-4 nuclei** (making up 9%).

**Feynman diagrams** are pictorial representation of the mathematical expressions which sketch out possible interactions between particles.




This **Feynman diagram** depicts the process of **electron-positron annihilation**, where an electron and a positron collide and produce two photons as they annihilate each other.

- **Double-beta decay** is the simultaneous beta decays of two neutrons inside an atomicnucleus, emitting two electrons and two electron antineutrinos. This phenomenon occurs in certain types of unstable atomic nuclei and is a rare process in comparison to single beta decay.

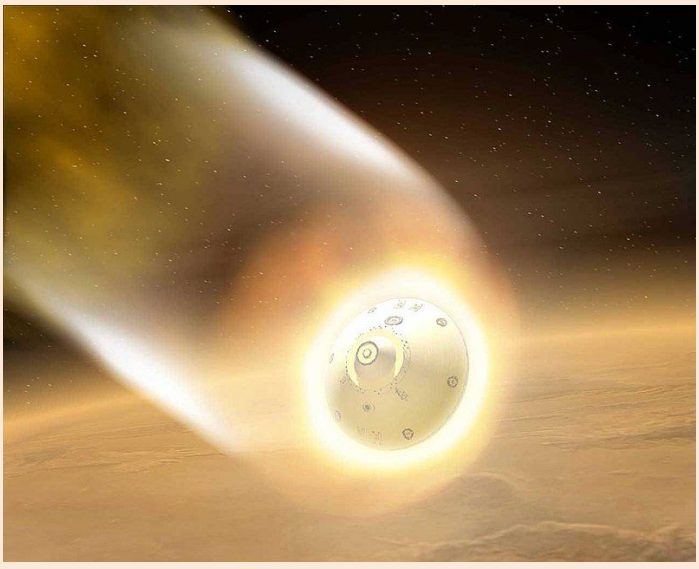


**Total energy of a molecule = electronic energy + translational energy + rotational energy + vibrational energy**

Phenomena characterized by energy greater than the square root of $\frac{\hbar c^5}{G}$, or occurring within spatial scales smaller than the square root of $\frac{\hbar G}{c^3}$, lie beyond the scope of explanation provided by the **Standard Model of Physics**.

## ✓ Atmospheric entry

The phenomenon whereby an object originating from outer space descends into and passes through the gaseous envelope surrounding a planet, dwarf planet, or natural satellite.



Artistic rendering of the entry of the **Mars Exploration Rover** (MER) **aeroshell** into the Martian atmosphere.

## ✓ Inverse beta decay

electron + proton → neutron + neutrino

**Takes place in stars of extremely high density.**

## Induced fission

Thermal neutron + Uranium 235 → Uranium 236 → X + Y

- X and Y denote the fragments from the fission process.

Induced fission refers to the process by which a nucleus is split into two or more smaller fragments when it is bombarded by a neutron or other particle. This process is commonly used in nuclear reactors and nuclear weapons to release large amounts of energy. In induced fission, a neutron collides with a heavy nucleus, such as uranium-235 or plutonium-239, causing the nucleus to become unstable and split into two smaller nuclei, along with the release of several neutrons and a significant amount of energy. The neutrons released during the fission process can then collide with other nuclei, leading to a chain reaction and the release of even more energy.

At the range of $10^{-15}$ m, the **strong force** is approximately 137 times as strong as electromagnetism, a million times as strong as the weak interaction, and $10^{38}$ times as strong as gravitation.



**Quarks → Hadron particles (protons + neutrons)**

✓ **Electron capture**

$_{Z}X^{A}$ + electron → $_{Z-1}X^{A}$ + electron neutrino

**The Planck scale → the scale at which the quantum effects of gravity become important.**

# Triple α process

$^{4}He + {}^{4}He \rightarrow {}^{8}Be + \gamma$

$^{8}Be + {}^{4}He \rightarrow {}^{12}C + \gamma$



This process provides the opportunity to produce heavier elements than $^{8}Be$.

✓ **Cold fusion**

A hypothetical type of nuclear reaction that is believed to occur at or near room temperature, without the need for high temperatures or pressures

**Modified Newtonian dynamics**

Hypothesis proposing a modification of Newton's law of universal gravitation to account for observed properties of galaxies

At energy of 14,000 GeV (i.e., 15,000 times the mass of a proton in units of energy): The velocity of the proton is 0.999999998c (so almost equal to c)

✓ The probability of two nuclear particles overcoming the Coulomb barrier in order to undergo nuclear fusion reactions is given by the equation:

$$P = e^{-\sqrt{\frac{E_G}{E}}}$$

where E is the kinetic energy of the particles and $E_G$ is the Gamow energy:

$$E_G = 2\mu c^2 \times (\pi \boldsymbol{\alpha} Z_1 Z_2)^2$$

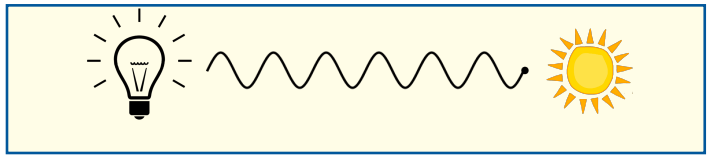
where $\mu = \frac{m_1 m_2}{m_1 + m_2}$ is the reduced mass of the two particles, $\boldsymbol{\alpha} = \frac{e^2}{4\pi\varepsilon_0 \hbar c}$ is the fine structure constant, c is the speed of light, and $Z_1$ and $Z_2$ are the respective atomic numbers of each particle.

✓ For two protons,

$$E_G = 2 \times \frac{m_p}{2} \times c^2 \times (\pi \times \boldsymbol{\alpha} \times 1 \times 1)^2 = 8.01088 \times 10^{-14}\ \text{J}$$

$T_{cmb} = \frac{T_{rec}}{1 + z_{rec}}$

- $T_{rec}$: Temperature at which recombination occurs
- $z_{rec}$: **Redshift at which recombination occurs**
- $T_{cmb}$: Temperature of cosmic microwave background



## ✓ Uncertainty principle:

$$\Delta E \times \Delta t \geq \frac{\hbar}{2}$$

**If the pions which mediate the nuclear force** – travels at the maximum possible speed of c, its range is roughly:

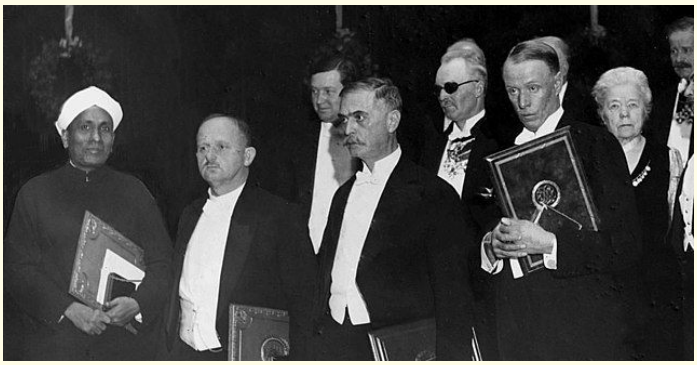
$$r \sim c \times \Delta t \sim \frac{\hbar c}{\Delta E}$$

For pions, $\Delta E = 135$ MeV or 140 MeV depending on whether they are neutral or charged. Plugging this in for $\Delta E$ gives $r \sim 1$ fm. Thus the nuclear force is negligible at distances greater than $\sim 1$ fm.

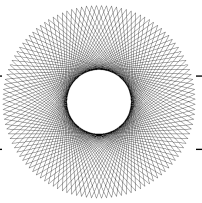
If the mass of the core of the white dwarf exceeds 1.44 solar mass, electrons are captured by the nuclei to avoid the violation of the Pauli principle:

$$e^- + (Z, A) \rightarrow (Z - 1, A) + \nu_e$$

The neutrinos escape the core taking away energy.



**NOBEL PRIZE WINNER 1930 from left Venkata Raman (physics), Hans Fischer (chemistry), Karl Landsteiner (medicine) and Sinclair Lewis (literature).**



A **protostar** is formed by the gravitational collapse of a huge mass of hydrogen gas. The collapse is halted when the nuclear fusion reaction starts and the star becomes stable. Once the fusion process is stopped the star again undergoes collapse. In small star, this collapse is halted by the degenerate electrons **(white dwarf)**. If the mass is high, once again the star collapse and is halted by degenerate neutrons **(neutron star)**. If the mass is still higher, then it collapses to the volume of space where gravity is extreme enough to prevent the escape of even the fastest moving photons **(black hole)**.





## ✓ Space burial

The act of sending the human remains into space through a launch vehicle or spacecraft. The idea of utilizing traditional rockets to send human remains into space was introduced by science fiction writer **Neil R. Jones** in his novella titled **"The Jameson Satellite."** This work was featured in the pulp magazine **Amazing Stories** in the year 1931.

## ✓ Defense Meteorological Satellite Program

## (DMSP)

A **United States Department of Defense program** that developed and operated a series of weather satellites. These satellites were primarily used for collecting and disseminating meteorological, oceanographic, and space environmental data to support military operations, as well as other government and commercial purposes.



Artist depiction of a **DMSP-5D2** (Defense Meteorological Satellite Program Block 5D2) satellite in orbit

## ✓ Space selfie

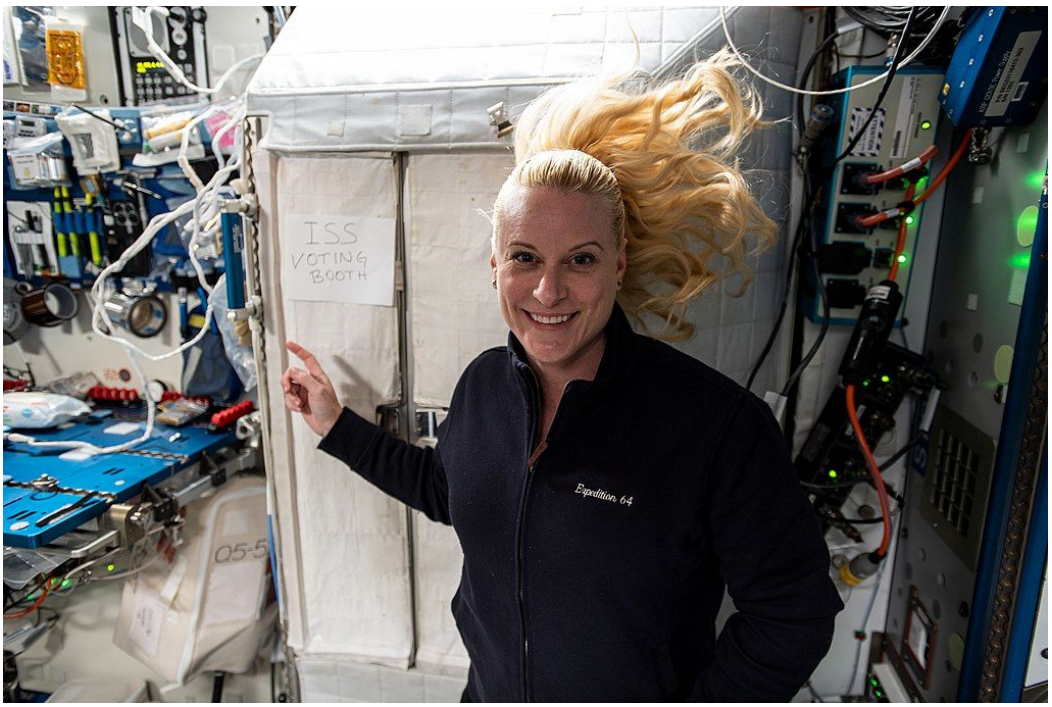
A self-portrait photograph taken in outer space, often shared on social media platforms.



In 1966, astronaut **Buzz Aldrin**, who was the pilot of the **Gemini 12 spacecraft**, captured a self-photograph while engaged in an extra-vehicular activity.

## ✓ Voting in space

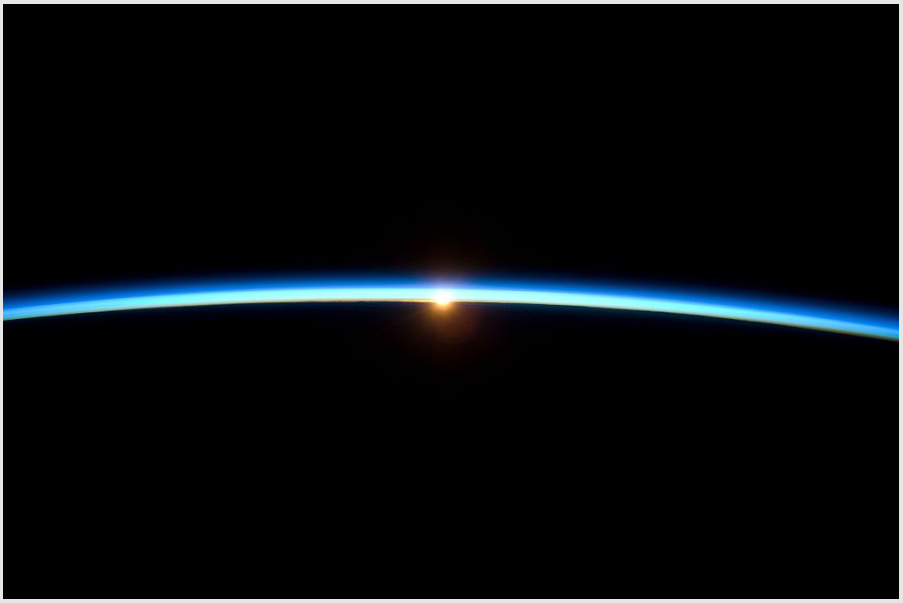
The process of enabling individuals who are in space, such as **astronauts** aboard a spacecraft or space station, to participate in **elections** or **decision-making processes** taking place on Earth.



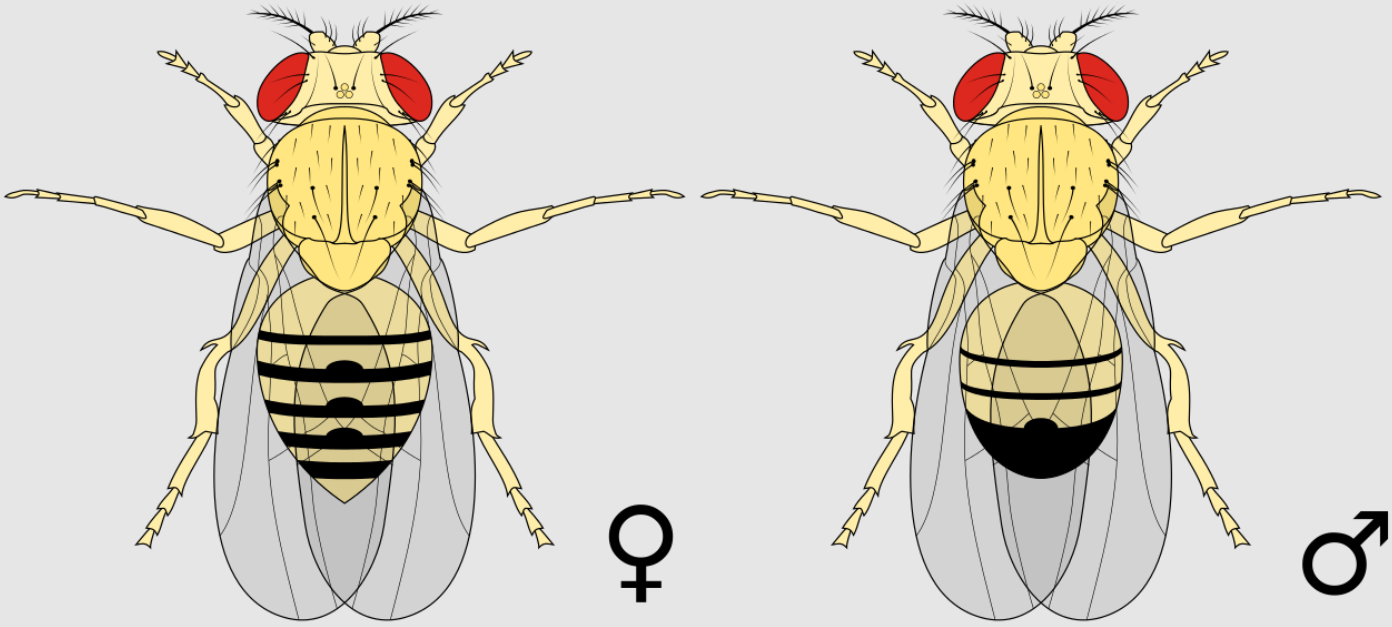

**Kathleen Rubins**, a two-time space voter, poses in front of a **"voting booth"** aboard the **International Space Station** in 2020.

## Overview effect

A special change in how some **astronauts** think and feel when they look at Earth from space. Researchers have described this effect as a feeling of amazement and feeling connected to something bigger, caused by seeing something very impressive.



The **International Space Station crew** captured this view of the Earth's atmosphere and the setting sun while **space shuttle Atlantis** connected with the station on the **STS-129 mission**.

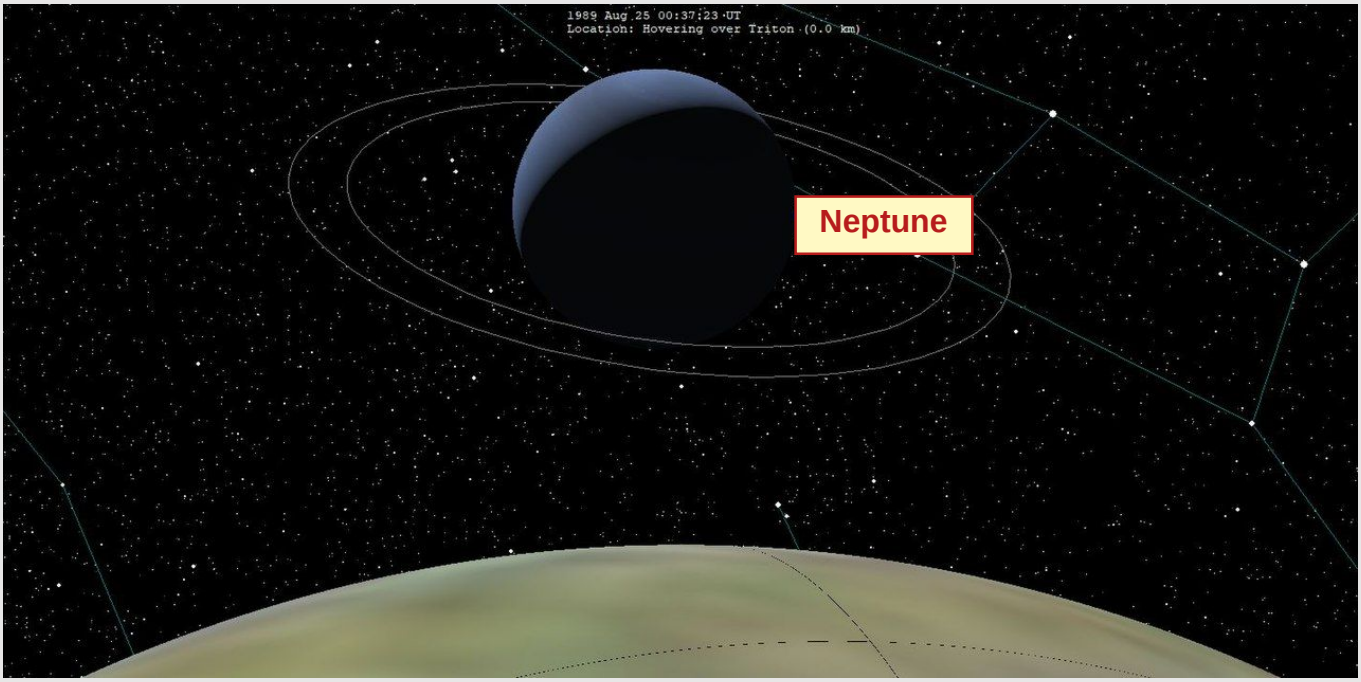


**Female (left) and male (right) Drosophila melanogaster**

The common fruit fly **Drosophila melanogaster** has been used to examine the effects of spaceflight on living organisms.

## ✓ Extraterrestrial sky

The sight of outer space as seen from the surface of a celestial body apart from Earth.



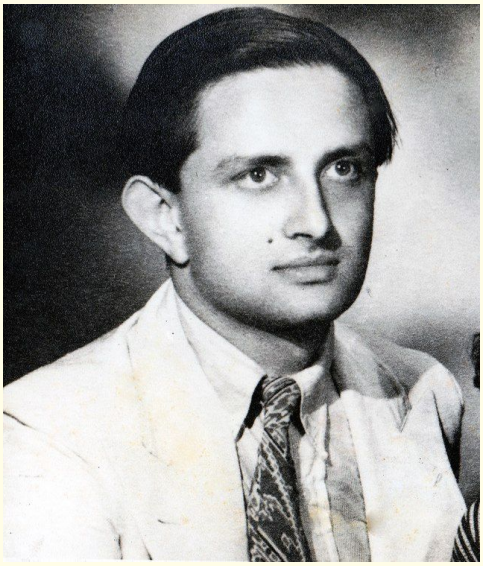

**Simulated view of Neptune observed from the surface of Triton.**

## Space food

A specially designed and processed food items intended for consumption by astronauts during their missions in outer space. These foods are meticulously crafted to meet the specific dietary needs and nutritional requirements of individuals working in a space environment.




A demonstration of food consumed aboard the **International Space Station** illustrates the utilization of magnets, springs, and Velcro to hold the cutlery and food pouches onto the tray.



**Vikram Ambalal Sarabhai**

**(12 August 1919 – 30 December 1971)**

An influential Indian scientist who made significant contributions to the fields of space research, nuclear power, and science education in India. He is often referred to as the **"Father of the Indian Space Program."**

✓ According to **virial theorem**, half the gravitational potential energy would be emitted in the form of radiation. Assuming the sun would emit radiation at the **same rate** throughout its life time, expression for life time of the sun is:

$$t_{life} = \frac{U}{2L}$$

where L is the luminosity of the sun. Using the expression for U, according to **linear density model**, we have:

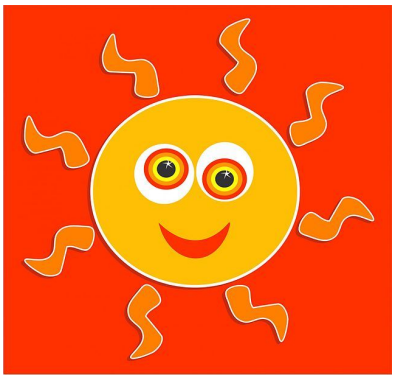
$$t_{life} = \frac{3GM^2}{10RL}$$

For sun:

$M \approx 1.98 \times 10^{30}$ kg

$R \approx 6.95 \times 10^{8}$ m

$L \approx 3.828 \times 10^{26}$ W



$t_{life} \approx$ 10 million years

Hence, according to **linear density model**, age of our sun is around **10 million years**. But geologists have proof that age of some of the rocks on the planet earth is greater than the above mentioned value. Hence the earth existed even before the birth of the sun– which is absolutely has no sense. Hence, gravitational potential energy cannot account for the age of stars and hence it cannot become the main source of energy in stars.

| Reaction | Neutrino energy |
|---|---|
| $p + p \rightarrow {}^2H + e^+ + \nu_e$ | $\leq 0.42$ MeV |
| $p + e^- + p \rightarrow {}^2H + \nu_e$ | 1.442 MeV |
| ${}^3He + {}^3He \rightarrow {}^4He + p + p$<br>${}^3He + {}^4He \rightarrow {}^7Be + \gamma$<br>${}^3He + p \rightarrow {}^4He + e^+ + \nu_e$ | $\leq 18.8$ MeV |
| ${}^7Be + e^- \rightarrow {}^7Li + \nu_e$ | 0.86 MeV |
| ${}^7Li + p \rightarrow {}^4He + {}^4He$<br>${}^7Be + p \rightarrow {}^8B + \gamma$<br>${}^8B \rightarrow {}^8Be^* + e^+ + \nu_e$<br>${}^8Be^* \rightarrow {}^4He + {}^4He$ | < 15 MeV |

The Sun emits around $2\times10^{38}$ electron neutrinos (with $E \leq 0.420$ MeV) per second.

The nuclear reaction that makes neutrino detection possible is:

$$\nu_e + {}^{37}Cl \rightarrow {}^{37}Ar + e^-$$

When a neutrino hits a chlorine atom, the chlorine is transformed into argon, and an electron is liberated

The special theory of relativity permits the existence of imaginary particles that have always moved with a velocity $v > c$. Such particles are called **tachyons**

**Surface gravity** is constant over the horizon of a black hole.

No naked singularity with Angular momentum > $(\text{Mass})^2$ may exist

**(Penrose conjecture)**

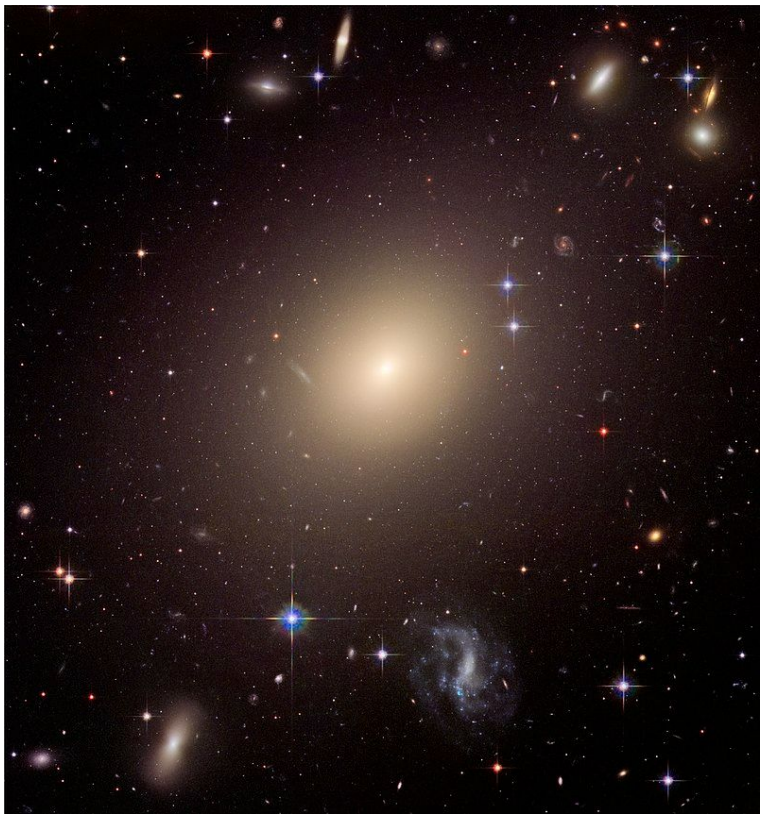
The temperature in the cosmic microwave background has decreased from $T_{emitted} = 3000K$ to $T_{observed} = 2.73K$ since its emission. The redshift is found via

$$z = \left( \frac{T_{emitted}}{T_{observed}} - 1 \right) \approx 10^3$$

**The cosmic microwave background has been redshifted approximately by a factor thousand since its emission.**

$\Delta E$ is the energy fluctuation during a time interval $\Delta t$. If $\Delta E \geq$ gravitational self-energy of the fluctuation, then the fluctuations are so significant that the spacetime cannot be described without a **quantum theory of gravity**.

There is no mass limit to the mass of a black hole. As there is no agency which can halt the collapse of the star, the entire mass of a star shrinks to a point of infinite density (**gravitational singularity**).



**ESO 325-G004, a typical elliptical galaxy.**



**Alhazen (Ibn al-Haytham), "the father of Optics"**

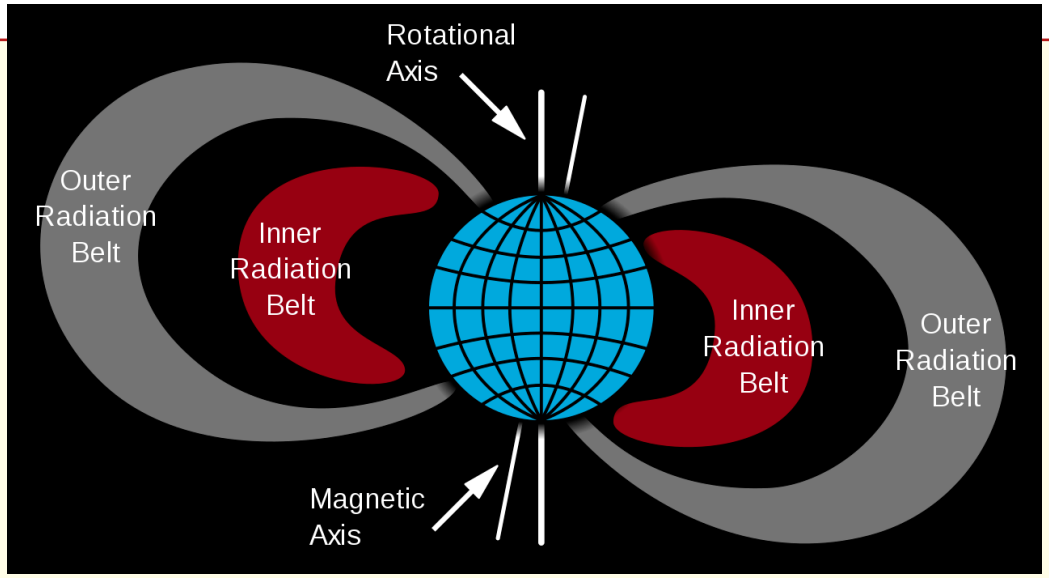
Hubble's law ($\frac{dR}{dt} = HR$) does not apply to galaxies bound together by gravitational forces, like the colliding galaxies.

✓ Newtonian gravity is a good approximation to **General Theory of Relativity** when

The gravitational field is weak

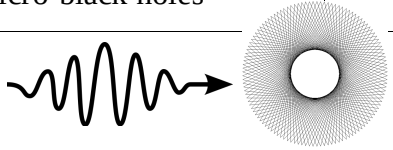
The velocities are small compared to the speed of light.






✓ **A cross section of Van Allen radiation belts**

| ✓ **Black Holes** | ✓ **Mass** |
|---|---|
| stellar-mass black holes | $3 – 30M_{sun}$ |
| super massive black holes | $10^5 – 10^9M_{sun}$ |
| intermediate-mass black holes | $10^3M_{sun}$ |
| primordial black holes | $M_{sun}$ |
| micro-black holes | Planck mass |



## Hagedorn temperature

**(**Boiling point of hadronic matter**)**

Temperature at which hadronic matter (i.e. **ordinary matter**) is no longer stable − it either "evaporate" or convert into quark matter.

**The thermal de Broglie wavelength of an electron:**

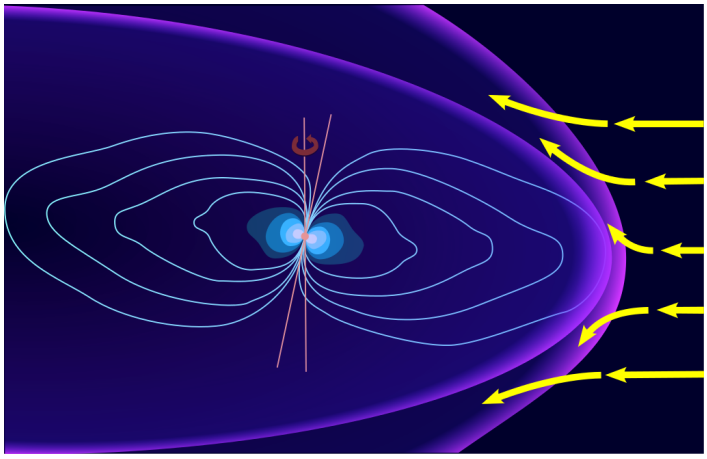
**The characteristic wavelength associated with the thermal motion of an electron**

$$\lambda_D = \sqrt{\frac{h^2}{2\pi m_e k_B T}}$$

$$\lambda_D = \sqrt{\frac{c_2 \times \lambda\!\!\!^{-}_C}{T}}$$

- $c_2$ → second radiation constant
- $\lambda\!\!\!^{-}_C$ → reduced Compton wavelength of the electron
- T → temperature

**At room temperature (25°C or 298 K), the thermal de Broglie wavelength of an electron is approximately 4.3179 nanometers.**



**Interactions between solar wind and Jovian magnetosphere**

**Bremsstrahlung radiation** is the radiation given off by a charged particle (most often an electron) due to its acceleration caused by an electric field of another charged particle (most often a proton or an atomic nucleus).

**The Einsteinian special theory of relativity rests on 2 postulates:**

- The laws of physics take the same form in all inertial frames.
- The velocity of light in vacuum (c) is a universal constant, which has the same value (~ 3 × $10^8$ m/s) in all inertial frames and independent of the motion of the light source.

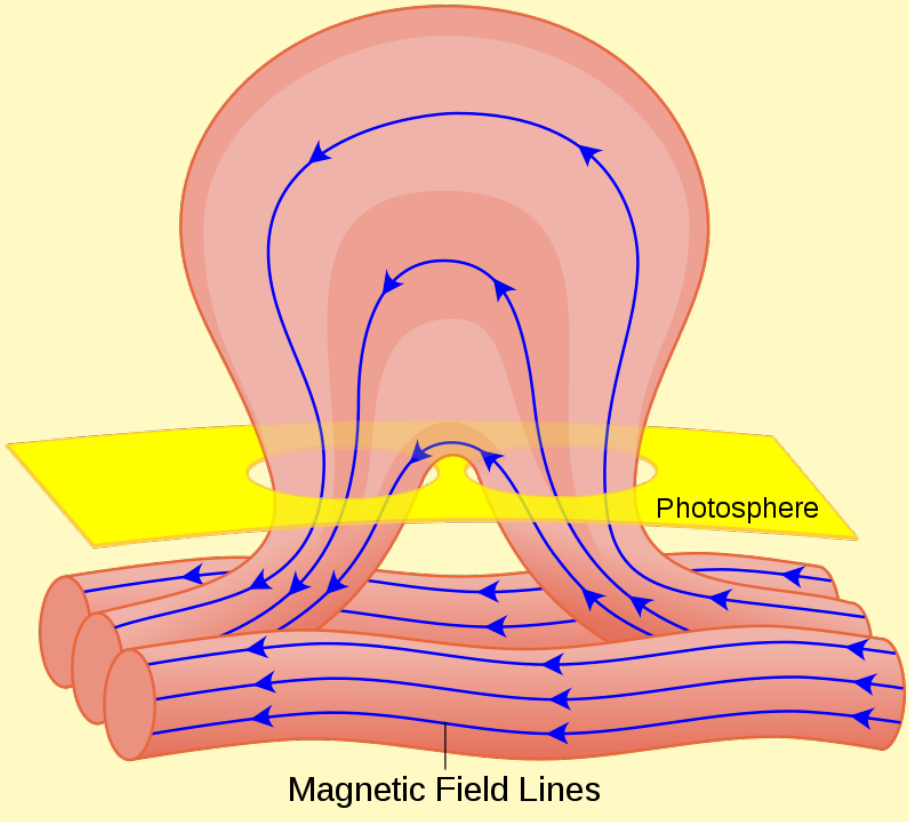



**Illustration of a solar flare's magnetic line structure and its origin caused by deformation of the magnetic field lines in the sun.**

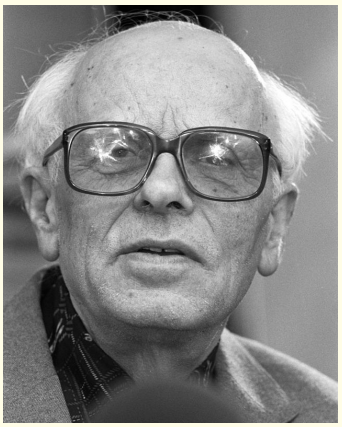
## ✓ Hund's rule:

When an atom has orbitals of equal energy, the order in which they are filled by electrons is such that a maximum number of electrons have unpaired spins.

- The matter antimatter asymmetry of the Universe is of order $10^{-10}$
- Li, Be, B, and Sc, Ti, V, Cr, Mn is significantly more abundant in cosmic rays.

✓ **3 conditions must be fulfilled in order to produce matter-antimatter asymmetry** (Andrei Sakharov, 1967) :

- C and CP violation of one of the fundamental interactions
- Non-conservation of baryon number
- There must have existed a state of thermodynamical non-equilibrium

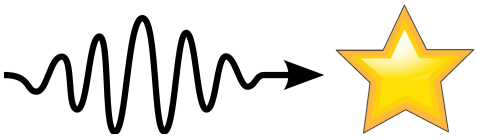


**Andrei Sakharov**

## Asteroid Mining

**Asteroid mining** is the concept of extracting valuable resources, such as metals and water, from asteroids and other celestial bodies. The idea of **asteroid mining** has been around for decades, but it has gained renewed interest in recent years due to the increasing scarcity of some resources on Earth and the potential to use space resources for future space exploration and settlement.

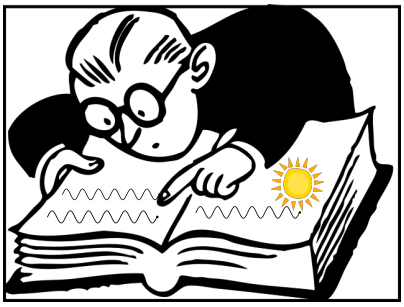
About 50000 years after the **Big Bang**, the mass density of the radiation was equal to the mass density of the matter. The universe had reached the **epoch of matter-radiation equality**.



- $z_{eq}$ → redshift at which the radiation and matter density are equal
  - ✓ $z > z_{eq}$ → radiation dominated
  - ✓ $z < z_{eq}$ → matter dominated

The **intensity** (brightness) **of light** at a given **radial distance** 'r' from the center of a **disc galaxy** is described by the formula:

$$I = I_0 \times \exp\left[-(r/h)^{\frac{1}{n}}\right]$$



where:

- I is the intensity at radial distance r.
- $I_0$ is the intensity (brightness) at the center of the galaxy.
- h is the scale length that describes how quickly the intensity of light decreases as we move away from the center of a galaxy. In simpler terms, it tells us how fast the brightness drops as we go from the center of the galaxy toward its outer regions.
- n is the **Sersic index** and for a disc galaxy: n = 1. This value indicates that the galaxy's light fades away smoothly and slowly as we move outward from its center.

$$I = I_0 \times \exp\left[-(r/h)\right]$$

The total luminosity 'L' of the galaxy can be calculated by the formula:

$$L = 4\pi h^2 \times I_0$$

## ✓ Space farming

Growing crops for **sustenance** (food) and **resource production** in space or on celestial bodies beyond Earth, equivalent to agricultural practices conducted on the Moon.



Expedition Five mission commander, Cosmonaut **Valery G. Korzun**, inspects a plant growth experiment within the **Zvezda Service Module** on the **International Space Station**.

## Generation ship

Also known as **generation starship**, is a theoretical interstellar vessel designed to travel at sub-light speeds. Due to the potentially extensive duration of hundreds to thousands of years needed to reach neighbouring stars, the initial inhabitants of a **generation starship** would age and pass away, transferring the responsibility of travel to their offspring who would carry forth the journey.

## Embryo space colonization

A speculative idea for **interstellar space colonization**, which involves deploying a robotic mission to a potentially habitable planet, dwarf planet, minor planet, or moon. This mission would carry frozen human embryos at an early developmental stage, or the necessary tools and instruments required to generate human embryos through technological or biological methods.

## Space toilet

A specialized sanitation device designed for use in space environments, ensuring the proper disposal of waste materials generated by astronauts during space missions.

## Space logistics

The planning, coordination, and management of various activities and resources involved in space missions, exploration, and operations. It encompasses a wide range of tasks and considerations necessary for the successful execution of space endeavours, including launching, transporting, and sustaining spacecraft, payloads, and equipment in space.

## Space manufacturing

The production of goods and materials in environments beyond Earth's atmosphere. This can include manufacturing in space stations, space habitats, on the Moon, or even on other planets.

## Cyclotron

A machine that accelerates charged particles or ions to high energies.

When a particle of e and speed v moves in a field of B, the Lorentz force in the circular orbit, evB, provides the necessary centripetal acceleration to maintain the circular motion:

$F = evB = \frac{m_0 v^2}{r}$ (where r is the radius of the orbit) $\longrightarrow$ $v = \frac{eBr}{m_0}$

The maximum kinetic energy of the particle when it reaches the outer most (largest) radius (r) of the cyclotron is given by: $KE_{max} = \frac{m_0 v^2}{2} = \frac{e^2 B^2 r^2}{2m_0}$.

The orbital frequency can be calculated from the expression: $\upsilon = \frac{v}{2\pi r} = \frac{eB}{2\pi m_0}$

- Cyclotron cannot accelerate electrons because electrons are of very small mass.
- A cyclotron cannot be used to accelerate neutral particles.
- Cyclotron cannot accelerate positively charged particles with large mass due to the relativistic effect.

For **relativistic particles**, the orbital frequency can be calculated from the expression:

$\upsilon = \frac{eB}{2\pi m}$ where $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$

When a proton of energy $E_{lab}$ strikes a stationary proton of mass $m_p$, the centre of mass energy in the reaction is given by: $E_{cm} = \sqrt{2m_p c^2 E_{lab}}$

Thus when a 30 GeV proton hits a stationary target, available energy for the reaction in the centre of mass is about 7.6GeV only.

| | |
|---|---|
| **Cosmography** | The branch of astronomy that maps and describes the main features of the universe. |
| **Cosmotheism** | The concept that the universe and God are identical. |
| **Cosmozoism** | The concept of the cosmos as alive. |
| **Geocentricism** | The concept that the earth is the center of the universe. |
| **Heliocentricism** | The concept that the sun is the center of the universe. |
| **Pancosmism** | The philosophical doctrine that the material universe is all that exists. |
| **Spencerianism** | The mechanistic evolution of the universe from relative simplicity to relative complexity. |
| **Teleologism** | Explanation by reference to some purpose, end, goal or function. |
| **Universology** | A science covering the whole ground of philosophy, of the sciences in their general aspects, and of social policy, or the collective life of the human world. |
| **Nebular hypothesis** | The theory that the solar system evolved from a hot gaseous nebula. |
| **Planetesimals hypothesis** | The theory that the solar system was formed by the gravitational accumulation of Planetesimals. |
| **ylem** → | The hypothetical initial substance of the universe from which all the elements are supposed to have derived.<br>→ **Originally thought as composed of neutrons at high temperature and density.** |
| **Cosmic consistency**<br>Launched on June 30, 2001 and named in honor of the late David Wilkinson of Princeton University | **(Wilkinson Microwave Anisotropy Probe data + other precision cosmological observations)**<br>pointing to a unified model that can predict key parameters such as: the age and shape of the Universe, the era for first star light, the Hubble constant, and the matter and energy content in the Universe. |
| **Cosmic horizon** | The limit of the observable universe |
| **Decoupling** | A period 380,000 years after the Big Bang<br>Photons separated from matter and propagated freely. |
| **Zero Kelvin**<br>(−273.15 degrees Celsius) | The complete absence of heat |

**Universe:** The totality of all that physically exists

The 4 fundamental forces — gravity, electromagnetic, weak and strong — are thought to be unified at a tiny fraction of a second ($5.4 \times 10^{-43}$ seconds).

"Sometimes ask myself how it came about that I was the one to develop the theory of relativity. The reason, I think, is that a normal adult never stops to think about problems of space and time. These are things which he has thought about as a child. But my intellectual development was retarded, as a result of which I began to wonder about space and time only when I had already grown up. "

## Einstein on relativity



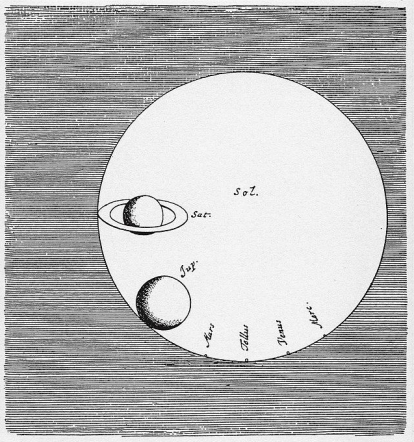
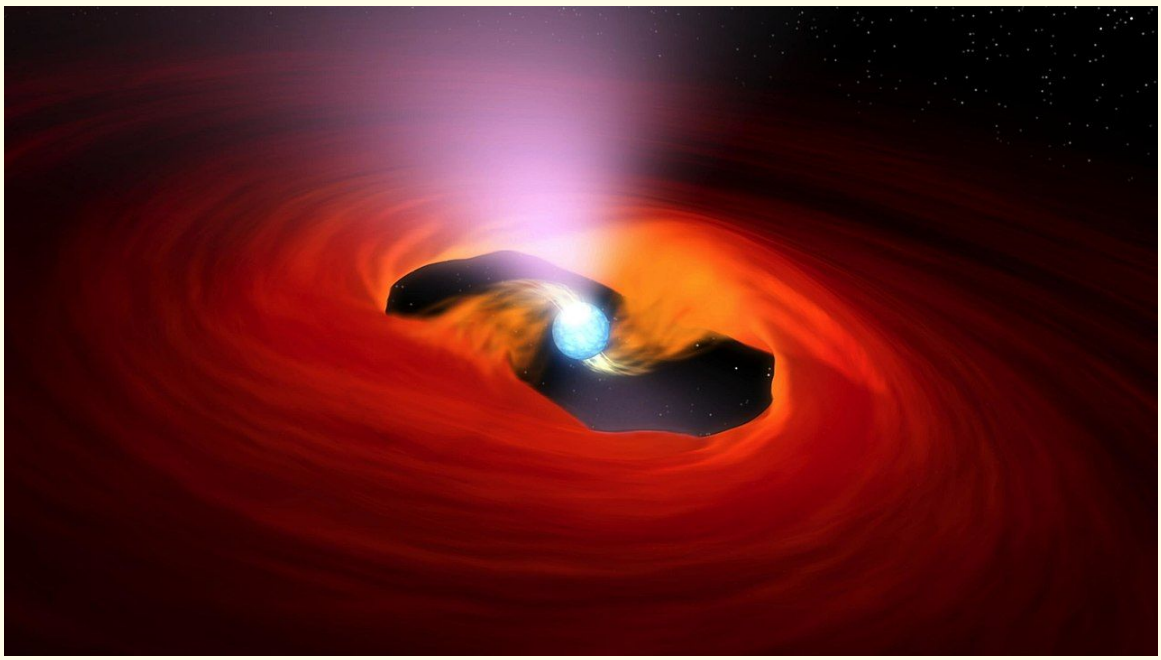
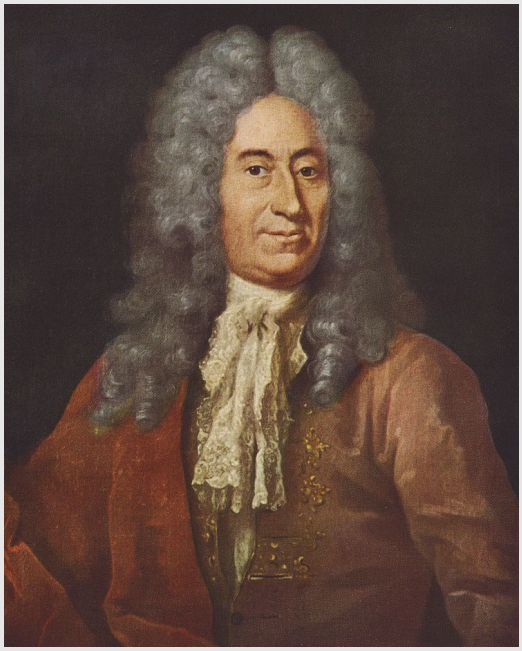



Illustration of the sizes of the sun and planets from Christiaan Huygens' 1698 book Cosmotheoros

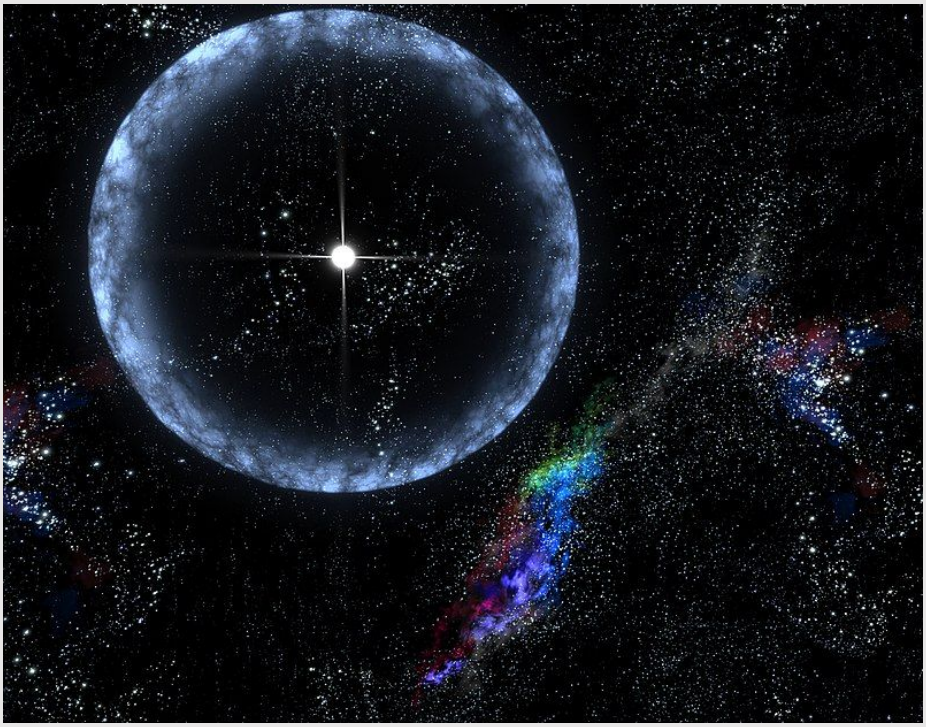
**Christian Huygens used Roemer's data to calculate the speed of light and found it to be large, but finite!**



**A digital simulation of a neutron star with an accretion disc that is blasting X-rays through its magnetic axis**



**Ole Rømer** was a Danish astronomer who, in 1676, made the first measurement of the speed of light.



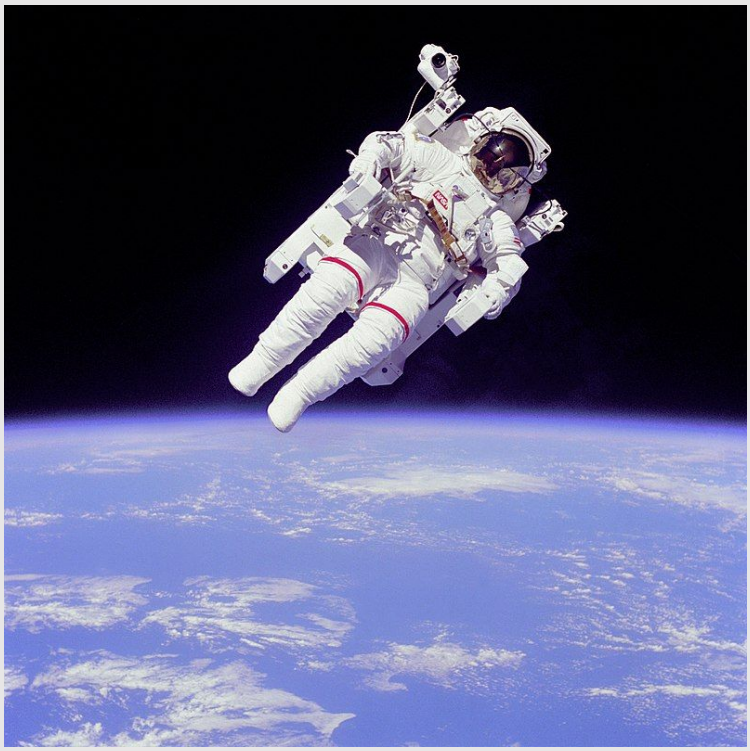
**NASA artist's depiction of a "starquake", also known as a "stellar quake"**

## Starquake

Also known as **stellar quake**, is derived from the more familiar concept of an earthquake on **Earth**, where stress accumulated within the Earth's crust is suddenly released in the form of seismic waves due to the movement of tectonic plates. Similarly, in the context of **a neutron star**, the immense gravitational forces and intense magnetic fields can cause stress to build up within the star's interior over time. Eventually, this stress can become so great that it triggers a sudden and violent release of energy, leading to the generation of seismic waves that propagate through the star's crust, causing the neutron star's crust to shake and vibrate, similar to how earthquakes cause the Earth's crust to tremble.

## Photodissociation region (PDR)

A region of the **interstellar medium** where **far-ultraviolet photons** from nearby stars dissociate molecules, such as **$H_2$**, into their constituent atoms. These **PDRs** are commonly situated near young, hot stars and hold a significant position in shaping the chemical processes occurring within the interstellar medium.

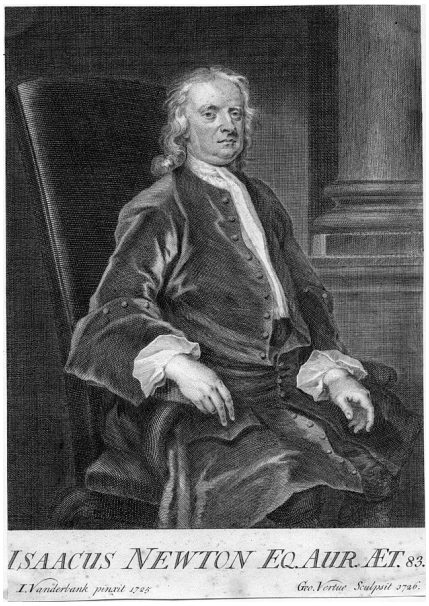


Astronaut **Bruce McCandless II**, a mission specialist, engages in an extravehicular activity (EVA), floating free in orbit with a space suit, a short distance away from the Space Shuttle Challenger's cabin.

**Newton's Second law of motion (for non relativistic case):**

$$F = m_0 a$$

$$m_0 = \frac{F}{a}$$




If net force on particle is zero, then acceleration of particle is also zero. Therefore in absence of force (F=0) the particle will remains at rest, which is first law of motion.

$$F = 0,\ a = 0$$

$$m_0 = \frac{0}{0} \longrightarrow \text{an operation that is not defined in mathematics}$$

"Everything is Light. In one of its rays is the destiny of the nations, each nation has its own ray in that great source of light, which we see, like the Sun. And remember, there is no man who has existed and who has not died!"

(**Everything is Light** The Incredible interview with Nikola Tesla)

**Eddington parameter:**

$$A = \frac{\text{Luminosity of the star}}{\text{Eddington Luminosity}}$$

The **Eddington parameter** is a measure of how close a star is to its theoretical limit of luminosity and how close it is to disrupting itself. It named after the British astrophysicist **Arthur Eddington**, who first derived this relation in the early 1900s. The **Eddington parameter** is an important quantity in the study of accretion disks around compact objects, such as black holes and neutron stars. If the **Eddington parameter** is less than one, the radiation pressure is weaker than the gravitational force, and the star is stable. If the **Eddington parameter** is greater than one, the radiation pressure dominates, and the star is unstable. This can lead to outbursts or explosions, such as in the case of a supernova or a gamma-ray burst.



**Sir Arthur Stanley Eddington**

The **Eddington luminosity** is the maximum luminosity that a star can have before it becomes unstable and its radiation pressure starts to push the outer layers of the star outward, causing it to expand and potentially leading to a catastrophic event such as a **supernova**.

**The Eddington Luminosity is given by:**

$$L_{Edd} = \frac{4\pi G M m_p c}{\sigma_T}$$

**The maximum luminosity that a star can achieve without being disrupted by the radiation pressure generated by its own light.**

where: G is the gravitational constant, M is the mass of the star, $m_p$ is the proton mass, c is the speed of light and $\sigma_T$ is the Thomson cross section.

$$A = \frac{\sigma T^4 4\pi R^2}{\left[\frac{4\pi G M m_p c}{\sigma_T}\right]} = \frac{\sigma T^4}{c} \times \frac{\sigma_T}{m_p} \times \frac{R^2}{GM}$$

Since:

$$\text{Radiation pressure} = P_{rad} = \frac{4\sigma T^4}{3c}$$

$$\text{Gravitational acceleration} = g = \frac{GM}{R^2}$$

$$\text{Opacity of the stellar material} = \kappa = \frac{\sigma_T}{m_p}$$

Therefore:

$$A = \frac{3 P_{rad} \kappa}{4g}$$

$$P_{rad} = \frac{4g}{3\kappa}, \text{ when } A = 1$$

**A value of 1 for the Eddington parameter indicates that the star is emitting radiation at its maximum possible rate without exceeding its Eddington luminosity**

## Gravitational coupling constant for proton:

$$\alpha_G = \frac{(\text{proton mass})^2}{(\text{Planck mass})^2}$$

$$\alpha_G = (\text{Planck time} \times \text{Compton angular frequency of the proton})^2$$

**Accretion luminosity** is the luminosity produced by a celestial object, such as a star or a black hole, as it accretes or pulls in matter from a surrounding disk or cloud. When matter falls onto a compact object like a black hole, neutron star, or white dwarf, it releases gravitational potential energy, which is converted into heat and radiation that we observe as accretion luminosity. The **accretion luminosity** can be estimated using the following formula:

$$L_{accretion} = \varepsilon \frac{dM}{dt} c^2$$

**Accretion Luminosity**

Radiative efficiency of the accretion process **(the fraction of the rest-mass energy of the accreted material that is converted into radiation)**

Rate at which a compact object is accreting mass from its surroundings




**Eddington, right, on a horse; possibly during the Fifth Conference of the International Union for Co-operation in Solar Research, held in Bonn, Germany, 1913**

$$A = \frac{L_{accretion}}{L_{Edd}} = \varepsilon \frac{dM}{dt} \times \frac{\kappa c}{4\pi G M}$$

Setting the accretion luminosity equal to the Eddington luminosity (A=1) gives us the maximum rate at which a black hole can accrete gas:

$$\text{Eddington accretion rate} = \frac{dM}{dt} = \frac{4\pi G}{\varepsilon \kappa c} \times M$$

If $\frac{4\pi G}{\varepsilon \kappa c} \rightarrow$ constant 'k':

$$\frac{dM}{dt} = kM$$

$$M = M_0 e^{kt}$$

# Eddington luminosity Derivation:

**The gravitational force inwards balances with the radiation force outwards.**

The gravitational force is given by:

$$F_{grav} = \frac{GMm}{R^2}$$

Radiation pressure at R:

$$P_{rad} = \frac{L}{c4\pi R^2}$$

$$F_{rad} = P_{rad}\kappa m = \frac{L\kappa m}{c4\pi R^2}$$

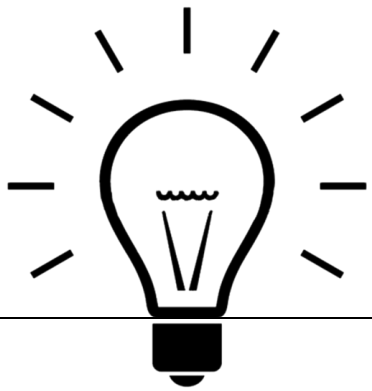
Balancing the two forces gives:

$$\frac{GMm}{R^2} = \frac{L\kappa m}{c4\pi R^2}$$

$$L = \frac{4\pi GMc}{\kappa}$$

For ionized hydrogen: $\kappa = \frac{\sigma_T}{m_p}$

$$L_{Edd} = = \frac{4\pi GMm_p c}{\sigma_T}$$



## Eddington luminosity

**Theoretical limit** on the luminosity of an astrophysical object, beyond which radiation pressure would overpower the gravitational attraction holding the object together.

Let's calculate the **Eddington luminosity** for a star with a mass of 10 solar masses. Using the values for the constants as:

$$L_{Edd} = \frac{4\pi G M m_p c}{\sigma_T}$$

$$L_{Edd} = \frac{4 \times 3.14 \times 6.673 \times 10^{-11} \frac{Nm^2}{kg^2} \times 10 \times 1.989 \times 10^{30}\ kg \times 1.672 \times 10^{-27}\ kg \times 2.99 \times 10^{8}\ m/s}{6.652 \times 10^{-29} m^2}$$

$$L_{Edd} \approx 1.25285487801 \times 10^{32}\ W$$

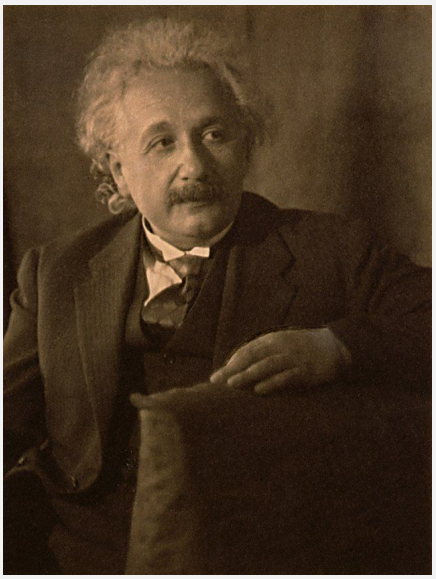
This is the **Eddington luminosity** for a star with a mass of **10 solar masses**. Any object with a luminosity higher than this limit will experience radiation pressure that is strong enough to disrupt its structure.

**For sun:**

$$L_{Edd} = \frac{4 \times 3.14 \times 6.673 \times 10^{-11} \frac{Nm^2}{kg^2} \times 1.989 \times 10^{30}\ kg \times 1.672 \times 10^{-27}\ kg \times 2.99 \times 10^{8}\ m/s}{6.652 \times 10^{-29} m^2}$$

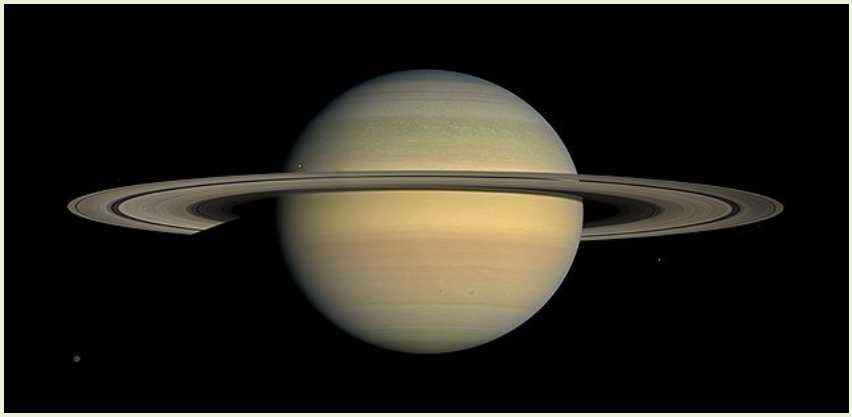
$$L_{Edd} \approx 1.25285487801 \times 10^{31}\ W$$

Therefore, the Eddington luminosity for the Sun is approximately **1.25285487801 × $10^{31}$ watts**. This means that the Sun's luminosity is well below its **Eddington limit**, and so it is not at risk of being disrupted by radiation pressure.

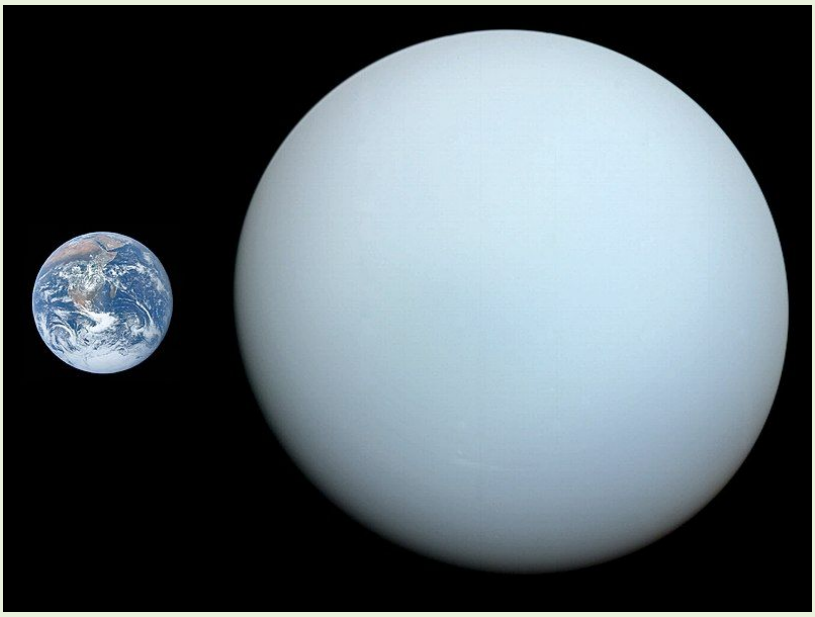





The 5-year-old Einstein



While **Galileo Galilei** did observe the **rings of Saturn** in 1610, he was actually unable to accurately identify what they were. At the time, he believed that they were two large moons or "handles" attached to the planet. It wasn't until later observations by other astronomers, such as **Christiaan Huygens** in the 1650s, that the true nature of **Saturn's rings** was discovered. It was eventually determined that the rings were made up of countless small particles of ice and rock orbiting the planet, and they have since become a major object of study for astronomers and planetary scientists.



**Earth** has a diameter of approximately 12,742 kilometers (7,918 miles), while **Uranus** has a diameter of approximately 50,724 kilometers (31,518 miles). **This means that Uranus is four times larger than Earth.**

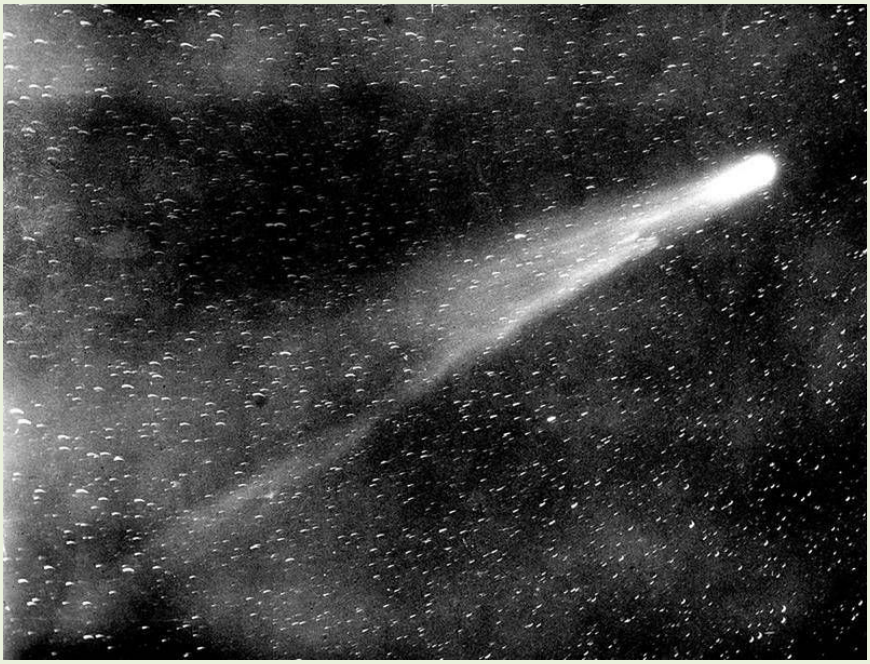



**Urbain Le Verrier**

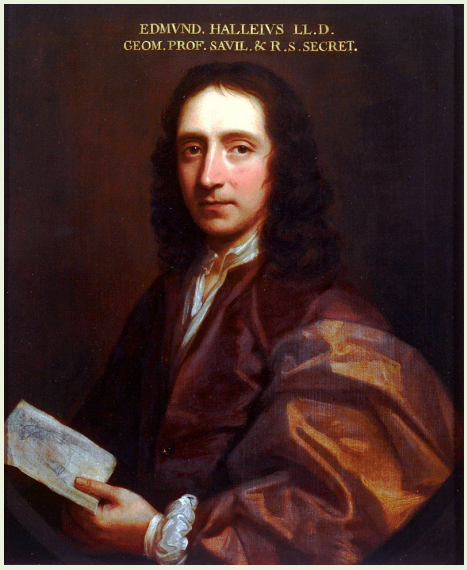


**John Couch Adams**

**Urbain Le Verrier** (1811−1877) was a **French astronomer and mathematician** who is best known for his role in the discovery of the **planet Neptune**. In the mid-19th century, astronomers had noticed discrepancies in the orbit of Uranus, which led some to suspect the existence of an unknown planet beyond it. **Le Verrier** used his expertise in **celestial mechanics** to calculate the possible location and size of this hypothetical planet. He sent his predictions to German astronomer **Johann Gottfried Galle**, who used them to successfully observe and confirm the **existence of Neptune** in 1846. **Le Verrier's discovery** of Neptune made him famous and earned him numerous awards and honors, including the Gold Medal of the **Royal Astronomical Society** and the title of **Chevalier of the Legion of Honor**. He also made significant contributions to the study of the **planet Mercury**, and was the first to accurately determine its distance from the Sun. In addition to his work in astronomy, **Le Verrier** was involved in the development of the French railway system and was a member of the **French Academy of Sciences**. However, he was known for his difficult personality and contentious relationships with other scientists, including British astronomer **John Couch Adams**, who had independently calculated the position of Neptune before **Le Verrier**, but did not receive the same recognition.



**Halley's Comet in 1910**




**Edmond Halley** (1656 −1742) was an English astronomer, geophysicist, mathematician, and who made substantial contributions to a number of scientific disciplines. He is most famous for predicting the orbit of the comet that bears his name, **Halley's Comet**, and correctly forecasting its return in **1758**, long after his death. Halley also made contributions to the understanding of tides, magnetic fields, and the Earth's magnetic poles. He published papers on various topics, including the trade winds, lunar observations, and solar eclipses. **Halley** was a **significant figure in the scientific community** and served as the **second Astronomer Royal of England**. His work laid the foundation for modern astronomy and inspired future generations of scientists.

## Bekenstein bound

If you try to store too much information within a compact spherical region, it will eventually collapse into a black hole. The **Bekenstein bound**, proposed by physicist **Jacob Bekenstein**, is a theoretical limit on the amount of information that can be accommodated within a defined spherical region of space without triggering the formation of a black hole. The **Bekenstein bound** is often expressed using the formula:

$$S \leq \frac{2\pi k_B RE}{\hbar c} = \frac{4\pi^2 RE}{\text{second radiation constant}}$$

where S is the entropy within a given spherical region of space, R is the radius of a given spherical region of space and $E = Mc^2$ is the total energy contained within that region, $\hbar$ is the reduced Planck constant, and c is the speed of light. In informational terms, with $S = k_B \times I \times \ln 2$, the bound is given by:

$$I \leq \frac{2\pi RE}{\hbar c \ln 2}$$

where I represents the maximum amount of information (in bits) that can be contained within a spherical region of space. This formula suggests that there is a fundamental limit to the amount of information that can be stored in a given spherical region of space, which is determined by the radius of the region and the total energy it contains.



## Amateur astronomy

A hobby where individuals find pleasure in the act of observing or capturing images of celestial objects in the sky, using only their naked eyes, binoculars, or telescopes.



## Sidewalk astronomy

Also known as **street corner astronomy**, involves the practice of placing telescopes in urban locations, either for profit or non-profit purposes, to offer entertainment and/or provide public

## Citizen science

Also referred to as **community science**, **crowd science**, **crowd-sourced science**, **civic science**, **participatory monitoring**, or **volunteer monitoring**, involves the engagement of the general public **(often termed as amateur or nonprofessional scientists)** in scientific research endeavors.

## Skygazing

Also referred to as **the act of looking up at the sky**, is an activity pursued for leisure or motivated by an interest in **amateur astronomy**.



**A 1498 illustration of skygazing**



$$a^2 - b^2 = (a+b)(a-b)$$

$$(a + b) = \frac{(a^2-b^2)}{(a-b)}$$

If a = b =1:

$$2 = \frac{0}{0}$$

In other words, the equation:

$$(a + b) = \frac{(a^2-b^2)}{(a-b)}$$

does not apply when a = b =1.

If an electron is accelerated to a velocity v by a potential difference V and then allowed to collide with a metal target, the maximum frequency of the X-ray emitted is given by the equation:

$$h\upsilon_{max} = \frac{m_e v^2}{2} = eV$$

$$h^2\upsilon_{max}^2 = \frac{m_e v^2}{2} \times eV$$

$$\upsilon_{max} = \frac{v}{2c}\sqrt{\upsilon_C K_J V}$$

where: $\upsilon_C$ is the Compton frequency, $K_J$ is the Josephson constant and c is the speed of light.

✓ The maximum frequency $\upsilon_{max}$ corresponds to a minimum wavelength:

$$\lambda_{min} = \frac{c}{\upsilon_{max}} = \frac{2c^2}{v\sqrt{\upsilon_c K_J V}}$$

"Science has never been defined by infallibility or superhuman perfection. It has always been about healthy skepticism, about putting every hypothesis to the test."

**— Ben Orlin, Math with Bad Drawings**

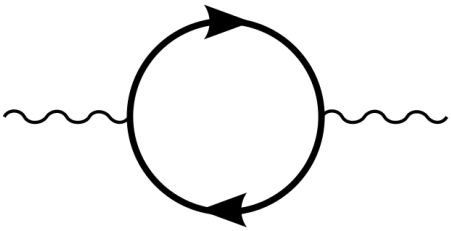
## ✓ Astrophotography

**Also known as astronomical imaging, is the photography or imaging of celestial objects, events occurring in space, or areas of the night sky.**

$$E^2 = p^2c^2 + m_0^2c^4$$

$$E^2 = \frac{h^2c^2}{\lambda^2} + \frac{h^2c^2}{\lambda_c^2}$$

$$E^2 = \frac{h^2c^2}{\lambda^2}\left(1 + \frac{\lambda^2}{\lambda_c^2}\right)$$



Since $E = mc^2 = \frac{p}{v}c^2$:

$$v = \frac{c}{\sqrt{1+\frac{\lambda^2}{\lambda_c^2}}}$$

If $\lambda = \lambda_C$:

**v= 0.7071c**

**Schönberg-Chandrasekhar limit** → $\frac{M_{core}}{M} = 0.37 \frac{\mu_{env}^2}{\mu_{core}^2}$

- $M_{core}$ → mass of the core.
- M →mass of the whole star.
- $\mu_{core}$ → mean molecular mass of the core.
- $\mu_{env}$ → mean molecular mass of the envelope.

Above **Schönberg-Chandrasekhar limit**, star core begins to contract rapidly. Contraction heats core, sets up temperature gradients, makes core radiate.

The retina of the eye is quite insensitive to these rays: the eye placed close to the apparatus sees nothing. It is clear from the experiments that this is not due to want of permeability on the part of the structures of the eye.

**Wilhelm Röntgen, 1895**

The basis of energy generation by nuclear fusion is that two reactants come together with sufficient collision energy to get close enough to experience the strong force. This force has a range ~$10^{-13}$ cm, i.e., about $\frac{1}{100{,}000}$ the size of the hydrogen atom.

**So two protons need to be no more than $10^{-13}$ cm apart in order to fuse together…**

**Black hole thermodynamics** is a **branch of astrophysics** that studies the physical properties of black holes, such as **temperature** and **entropy**, as they relate to thermodynamic systems. It shows that black holes have **entropy** proportional to the **surface area** of their event horizon, and that they emit thermal radiation, known as **Hawking radiation**, with a **temperature** that increases as their **mass** decreases. These findings have significant implications for our understanding of **quantum mechanics** and the **laws of gravity**.



## ✓ Fermi-Dirac statistics

Named after physicists **Enrico Fermi** and **Paul Dirac**, describe the distribution of particles with **half-integer spin**, such as **electrons**, in a **quantum mechanical system**. This play a vital role in understanding how these particles occupy energy levels in various states, particularly in situations where the **Pauli exclusion principle** applies, preventing identical particles from occupying the **same quantum state** simultaneously.

## ✓ Relativistic case:

KE = $\sqrt{p^2c^2 + m_0^2c^4}$, pc >> $m_0c^2$. Therefore: KE = pc

## ✓ Multi-messenger astronomy

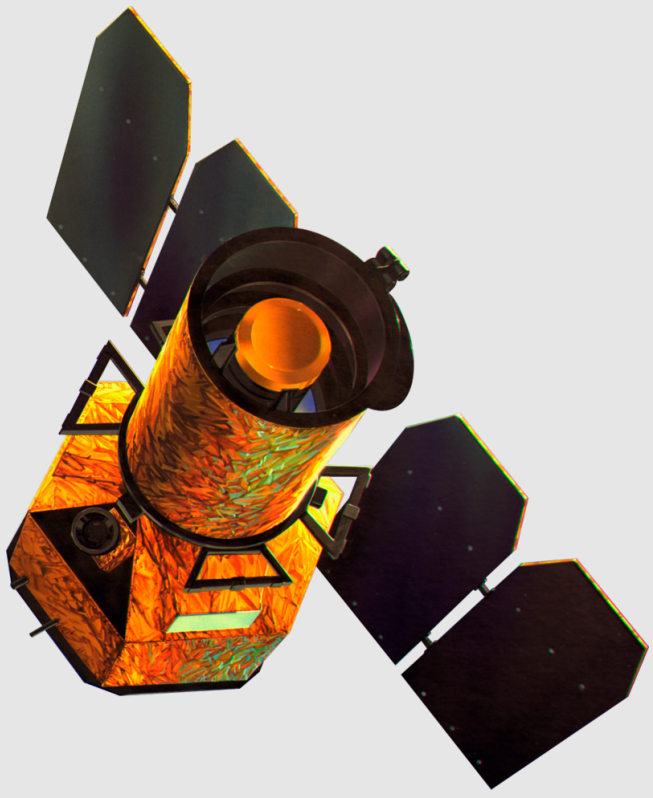
A **cutting-edge approach** in astrophysics that involves studying **cosmic phenomena** using multiple types of **signals** or **messengers**, such as **electromagnetic radiation** (like visible light, radio waves, and X-rays), **neutrinos**, **cosmic rays**, and **gravitational waves**. By combining information from various messengers, scientists gain a more comprehensive and accurate understanding of astrophysical events and objects.

## ✓ Optical window

A range of wavelengths that are not obstructed by the Earth's atmosphere.

## ✓ Radio window

A specific range of frequencies of electromagnetic radiation that have the ability to penetrate the Earth's atmosphere without being absorbed or scattered by the atmosphere.



✓ An artistic representation depicting the **GALEX** (Galaxy Evolution Explorer) spacecraft.

An **orbiting space telescope** launched by **NASA** with the purpose of observing the cosmos using ultraviolet wavelengths. Its mission was to study the timeline of star formation throughout the universe.

## ✓ Bose-Einstein statistics

The branch of **quantum statistics** that applies to systems of particles with zero or integral spin that do not obey the **exclusion principle**. In this **statistical framework**, particles can occupy the **same quantum state** simultaneously, unlike particles that follow the **exclusion principle**, which is described by **Fermi-Dirac statistics**.



Scientist and mathematician from India, whose name **Dirac** used to coin the term **"bosons"** to describe particles that follow **Bose-Einstein statistics**.

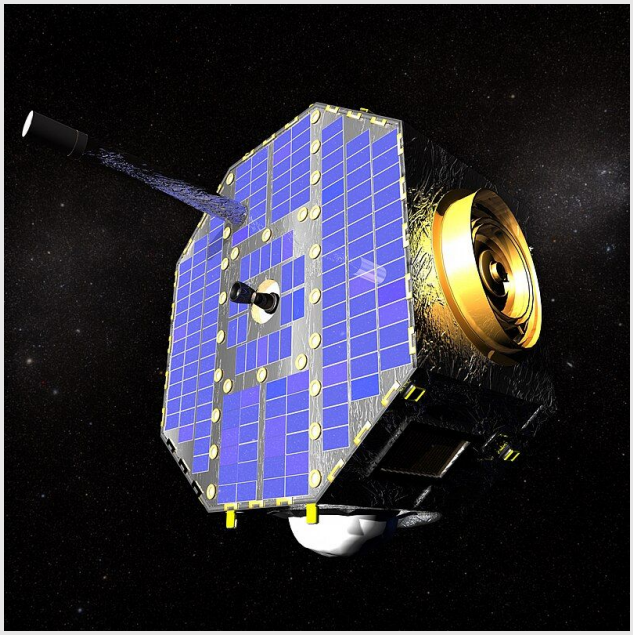
## Neutrino astronomy

A fascinating branch of **astronomy** that involves the observation of astronomical objects using **neutrino detectors** in specialized observatories. **Neutrinos** are elementary particles that are characterized by their weak interaction with matter, so they can travel long distances without being absorbed or scattered by matter. This unique property makes them ideal for studying distant astronomical objects, such as **supernovae** and **neutron star mergers**.

# ✓ Stephen Hawking: An Unfettered Genius



On Monday, April 21, 2008, at **George Washington University's Morton Auditorium** in Washington, **Dr. Stephen Hawking**, a professor of mathematics at the University of Cambridge, gives a speech titled **"Why we should travel into space"** as part of a series celebrating **NASA's 50th Anniversary**.



Artistic conception of the **Interstellar Boundary Explorer** (IBEX) satellite, a **NASA** satellite positioned in Earth's orbit that employs **energetic neutral atoms** (ENAs) to explore the interactions between solar wind plasma and the interstellar medium at the boundary region of our Solar System.



**W. M. Keck Observatory**, an **astronomical observatory** featuring a pair of telescopes situated at an altitude of 4,145 meters (13,600 feet) near the summit of **Mauna Kea** in the U.S. state of Hawaii.

## ✓ Astroparticle physics

Also known as **particle astrophysics**, is a specialized field within **particle physics** that examines elementary particles originating from celestial sources, exploring their connections with **astrophysics** and **cosmology**.

## Urca process

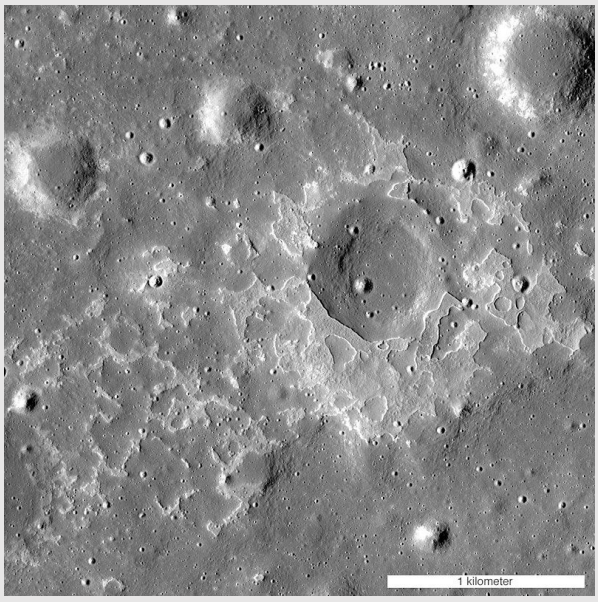
A specific reaction that involves the emission of a **neutrino** from a **baryon**. This phenomenon is believed to play a role in releasing energy from **white dwarfs** and **neutron stars**. The process can occur through various pathways, generally involving a **baryon** either absorbing or releasing a **lepton** (like an **electron**), with the emission of a **neutrino** during the reaction. As a consequence of this process, these celestial bodies experience accelerated cooling (referred to as **Urca-process cooling**) due to the rapid escape of neutrinos from their interiors.



**Visual from space:** The curved surface of the planet Earth

## Moon illusion

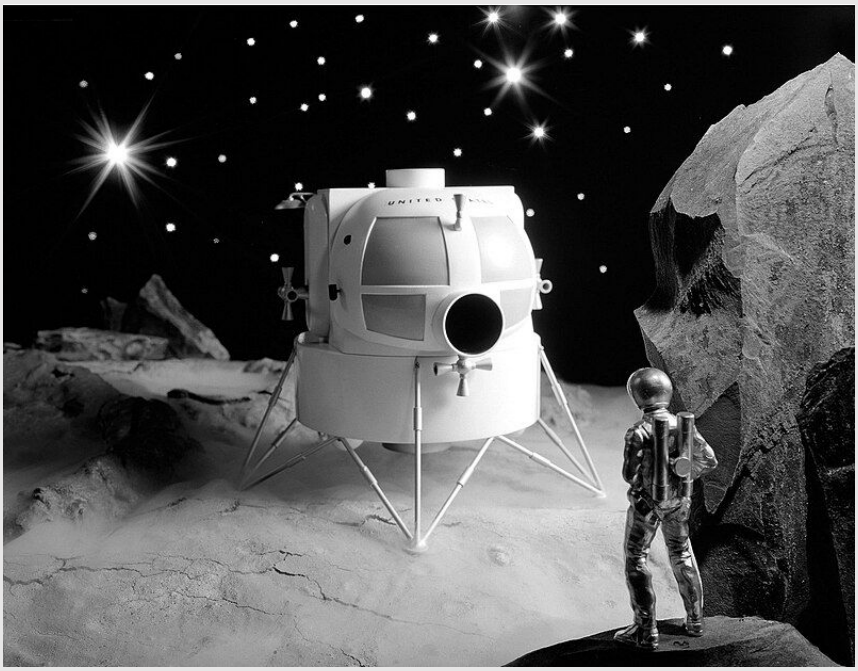
An optical phenomenon **(optical illusion)** that makes the Moon appear larger when it's near the horizon compared to when it's higher up in the sky.




The existence of volcanic deposits on the Moon provides substantial evidence of past **lunar volcanism**. These deposits indicate that volcanic activity once occurred on the Moon, contributing to its geological history and shaping its surface features.

## Moon landing

Also referred to as a **lunar landing**, is the successful landing of a spacecraft on the **Moon's surface**. This achievement encompasses missions involving both **human crews** and **robotic exploration**.



A conceptual model of the **Apollo Lunar Excursion Module** created in 1963.

A **spacecraft** designed and used by **NASA** during the Apollo program for landing **astronauts** on the Moon.

## Selenography

Also referred to as **lunar geography** or **selenodesy**, is the scientific discipline that focuses on the examination and analysis of the surface and physical characteristics of the Moon.

**Particle physics** is a subfield of physics that studies the fundamental building blocks of matter and their interactions. It involves the study of **elementary particles**, such as electrons, protons, and neutrinos, as well as the forces that govern their behaviour, such as the **electromagnetic**, **weak**, and **strong forces**. One of the key goals of particle physics is to understand the nature of the universe and its basic components. To do this, **particle physicists** use a variety of experimental techniques, including accelerators, detectors, and particle colliders, to create and study high energy particles. These experiments help us learn about the properties of the particles, their interactions, and their behaviour under different conditions.



One of the most important theories in **particle physics** is the **Standard Model**, which is a theoretical framework that describes the behaviour of elementary particles and their interactions. The **Standard Model** includes the **Higgs boson**, which is believed to be responsible for giving particles mass. However, the **Standard Model** has some limitations and does not explain some phenomena, such as **dark matter** and **dark energy**. Hence, **particle physicists** are actively searching for evidence of physics beyond the **Standard Model**, which could help us better understand the universe and its components.



**Particle physics** is an important field of research as it has many practical applications, including in **medical imaging** and **radiation therapy**, **energy production**, and **materials science**. It also has the potential to help us understand some of the biggest mysteries of the universe, such as the nature of **dark matter** and the unification of all forces.

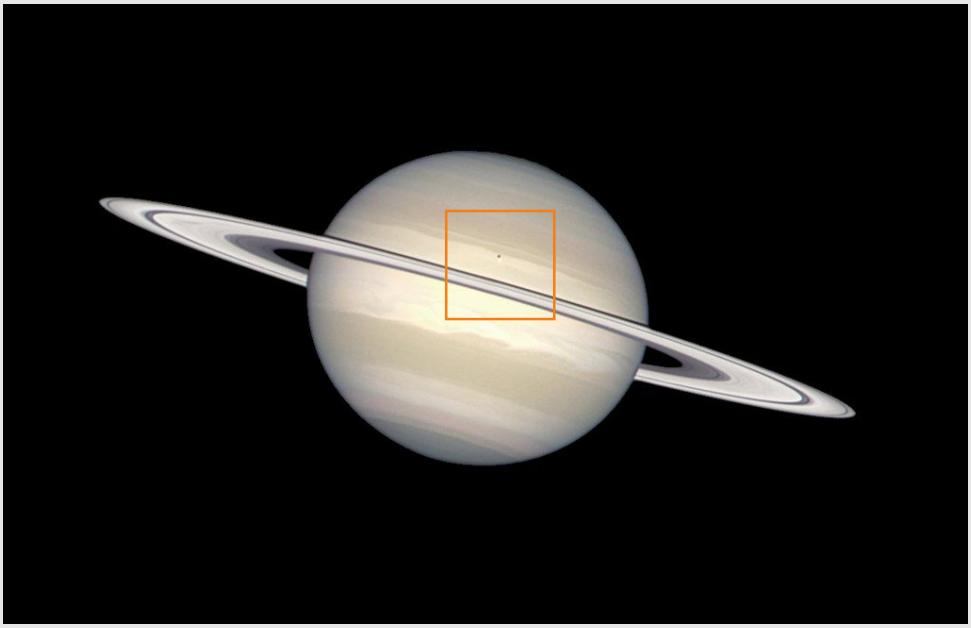


**There are several challenges and limitations in the field of particle physics:**

- **Cost:** Experiments in particle physics require large amounts of funding, as they often involve the construction of **massive particle accelerators** and **detectors**.
- **Technical difficulties:** Building and operating **particle accelerators** and **detectors** is a challenging task, and requires a high level of technical expertise.
- **Understanding the data:** Interpreting the data collected by **particle physics** experiments can be difficult, as it requires a deep understanding of both the experiment and the underlying physics.

- **Theoretical limitations:** While the field of **particle physics** has made many advances in recent decades, there are still many unanswered questions and theoretical limitations that must be addressed.
- **Limited access to particle accelerators:** Particle accelerators are complex and expensive experimental tools used by physicists and researchers to study the fundamental properties of particles and the nature of the universe. Due to their **high cost**, **technical requirements**, and **limited availability**, access to **particle accelerators** is limited. Researchers from around the world often have to compete for time to conduct experiments, which can slow the pace of research in particle physics and related fields.
- **Detection of dark matter:** Despite extensive efforts by the scientific community, understanding the nature of **dark matter** and **dark energy** – which make up most of the universe's mass-energy content – remains an immense hurdle. The elusive nature of **dark matter** has resulted in a considerable challenge for physicists to detect and study it. This challenge ranks among the most substantial and intricate problems within the field of **particle physics**.

Overall, **particle physics** is a complex field that faces many challenges and limitations, but it continues to make important contributions to our understanding of the universe.



The **Saturn's rings** consists mostly of icy fragments and dust particles. The **little dark spot** on **Saturn** which is caused by the shadow cast by its moon, **Enceladus**.

## Moon rocks

Also known as **lunar rocks**, are rocks that originate from the Moon. These include materials gathered by humans during their **lunar exploration missions** and rocks that have naturally been propelled from the Moon's surface, eventually landing on Earth as **meteorites**.

## Lunar Receiving Laboratory (LRL)

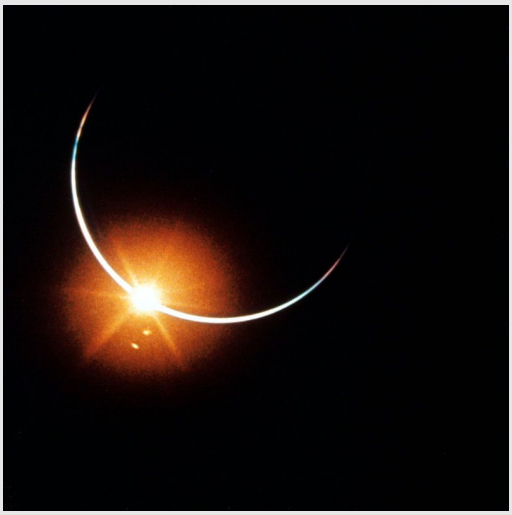
An establishment located at **NASA's Lyndon B. Johnson Space Center** (Building 37). It was specifically designed to keep astronauts and materials from the Moon separate from Earth to minimize the risk of introducing any potential lunar pathogens into Earth's environment.



The **Lunar Receiving Laboratory** shortly after it was built.



The **Venus In-Situ Explorer**, part of **NASA's New Frontiers program**, aims to enhance our understanding of the climate change mechanisms responsible for **Venus' current harsh environment**. Additionally, it seeks to establish the foundational framework for a potential future mission focused on collecting samples from **Venus**.



Onboard the **Apollo 12 mission** in 1969, **astronauts** witnessed a **solar eclipse** from deep space, capturing an awe-inspiring moment when the Earth's atmosphere was illuminated by the Sun's light from behind.

## PHOTOMETRY



**Measurement of light in terms of its perceived brightness to the human eye**

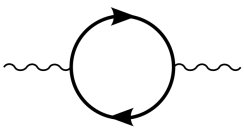
## HELIOPHYSICS

**Understanding the Sun and its interactions with Earth and the solar system**

## HELIOSEISMOLOGY

**Understanding** the structure and dynamics of the Sun through its oscillations

## ASTEROSEISMOLOGY



**Understanding** the internal structure of starsthrough its oscillations

**Black hole physics** is a complex and challenging field of study, and there are several problems that scientists have yet to fully resolve:

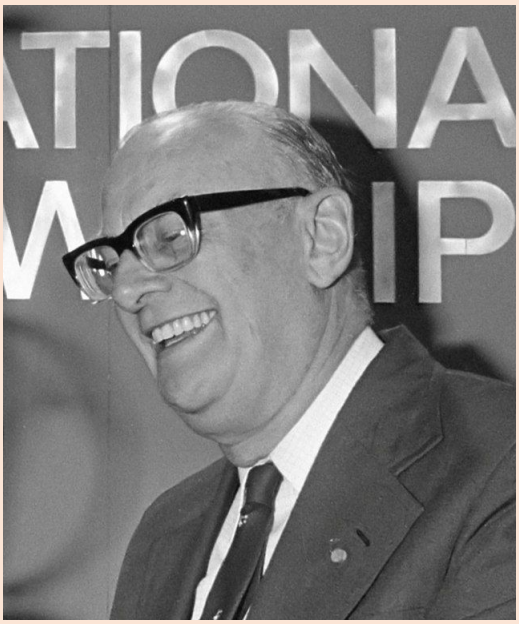
- **Information loss paradox:** One of the biggest problems in **black hole physics** is the **information loss paradox**, which is like a mystery where we're trying to understand what happens to the details of things that fall into a black hole. According to **general relativity**, the information is trapped behind the event horizon and can never escape. But according to **quantum mechanics**, the principle of **information conservation** holds strong. This means that the information must somehow be encoded in the **Hawking radiation** that is emitted by the black hole as it evaporates. Scientists have yet to find a solution to this **paradox** that is consistent with both **general relativity** and **quantum mechanics**.
- **Singularity problem:** Another major problem in black hole physics is **the singularity problem**, which states that the **laws of physics** break down at the **singularity**, the centre of a black hole − which is a point of infinite density and temperature. Scientists are still working to develop a theory that can describe the conditions at the singularity and explain what happens to matter and energy that approach it.
- **Firewall paradox:** The **firewall paradox** is a complex and unresolved problem in black hole physics, which states that the **firewall** would exist at the black hole's event horizon, and would remain undetectable to observers outside the event horizon. The information of matter falling into a black hole would be destroyed at its event horizon by an incredibly hot and chaotic assembly of particles at the **firewall**, contradicting the **principles of quantum mechanics** that demand information preservation.
- **Black hole evaporation:** Black holes are thought to evaporate over time due to the emission of **Hawking radiation**, which is caused by **quantum mechanical effects**. However, the rate of evaporation and the final state of a black hole are not well understood.

These problems are among the biggest challenges facing scientists in the field of **black hole physics**, and they are the subject of ongoing research and discussion. Solving these problems will require a deeper understanding of the **laws of physics** and a **new theory** that can reconcile the seemingly conflicting principles of **general relativity** and **quantum mechanics**.

# Atomic physics

The study of atoms, their structure and behaviour. It involves the study of electrons, protons and neutrons, their interactions and the electromagnetic forces between them. It also involves the study of **atomic spectrum**, which is the light emitted or absorbed by an atom, and the study of **atomic structure**, which is how electrons are arranged in shells around the nucleus. **Atomic physics** is important for understanding the behaviour of matter and for explaining chemical reactions. It also has many practical applications, ranging from atomic clocks and medical imaging to the generation of atomic energy.

**"I'm sure the universe is full of intelligent life. It's just been too intelligent to come here. "**



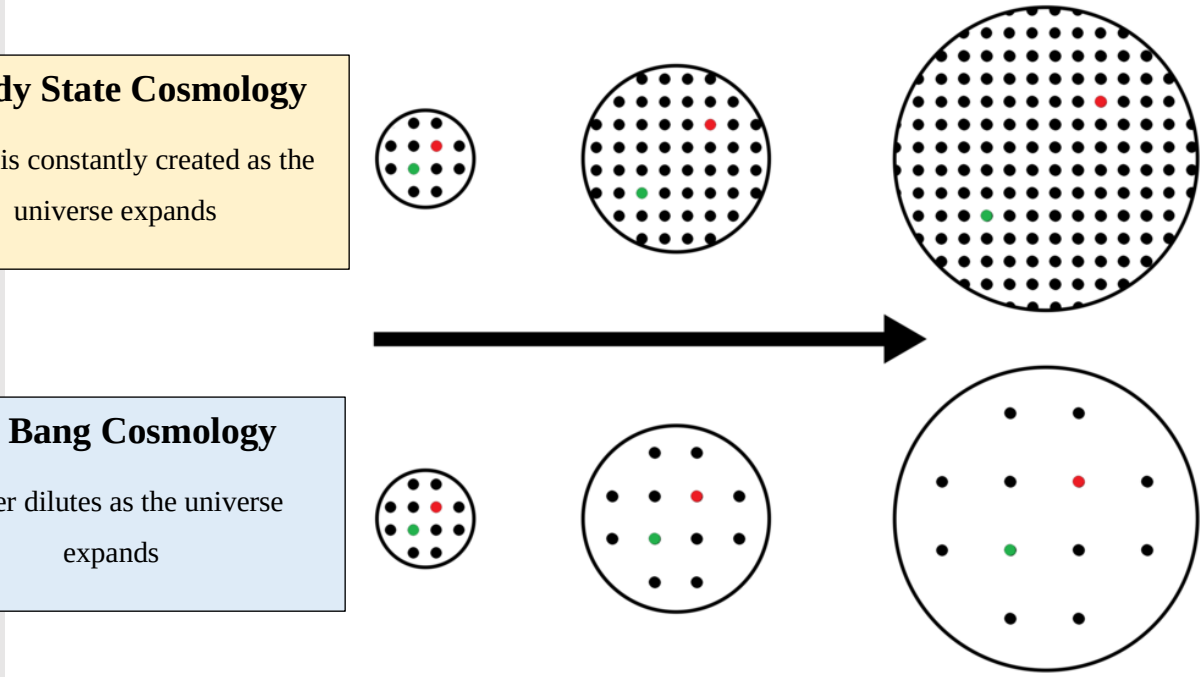
**— Arthur C. Clarke**

## Steady State Cosmology

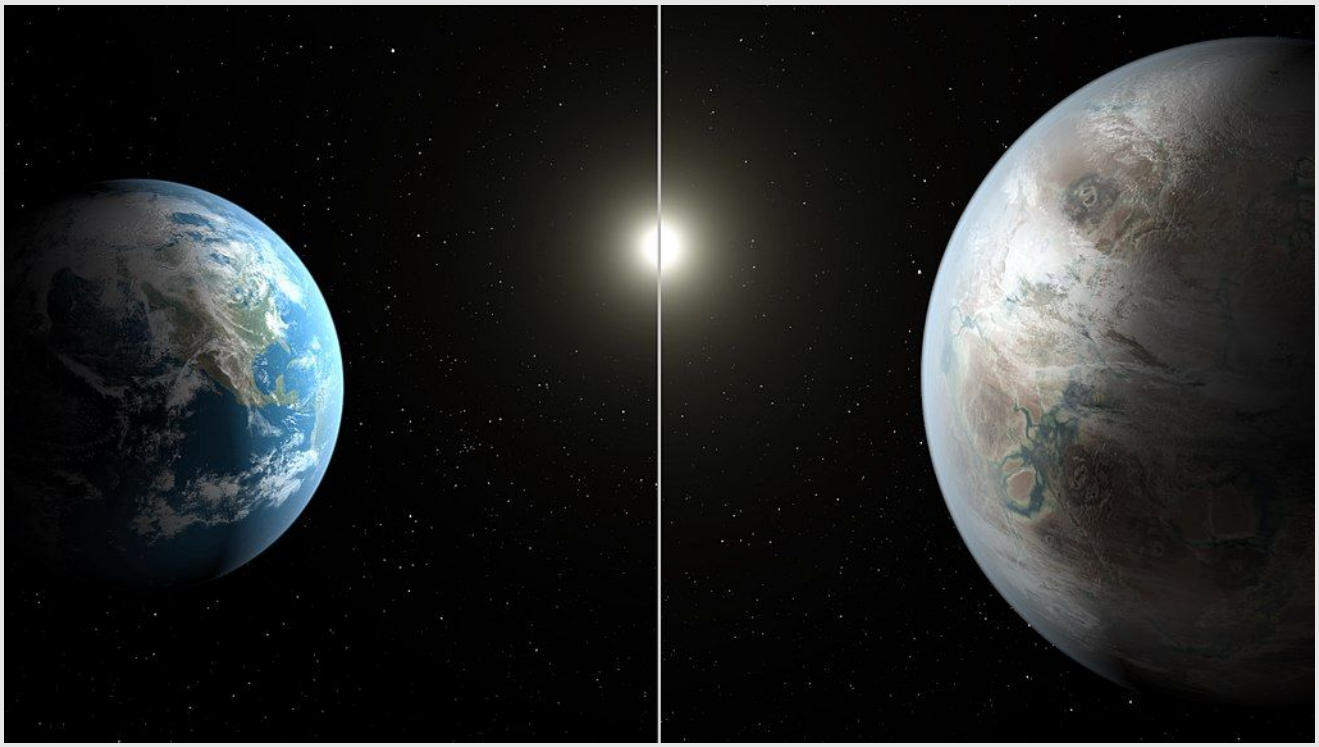
Matter is constantly created as the universe expands

## Big Bang Cosmology

Matter dilutes as the universe expands



In the context of the **Big Bang theory**, the Universe's expansion leads to the gradual dilution of matter as time progresses, whereas within the **Steady-State Theory**, a continuous process of matter creation maintains a consistent density throughout time.



Depicted artistically, this illustration presents a comparison between **Earth** (positioned on the left) and a **super-Earth exoplanet** orbiting within the inner edge of the **habitable zone** of the sun-like star **Kepler-452**, specifically **Kepler-452b**, which is about 60 percent larger in diameter.

Do I have faith? We are each free to believe what we want, and it's my view that the simplest explanation is that there is no God. No one created the universe and no one directs our fate. This leads me to a profound realisation: there is probably no heaven and afterlife either. I think belief in an afterlife is just wishful thinking. There is no reliable evidence for it, and it flies in the face of everything we know in science. I think that when we die we return to dust. But there's a sense in which we live on, in our influence, and in our genes that we pass on to our children. We have this one life to appreciate the grand design of the universe, and for that I am extremely grateful."

— **Stephen Hawking, Brief Answers to the Big Questions**

**Hubble's Law:**

$$\frac{da}{dt} = Ha$$

$a \rightarrow$ scale factor of the universe

Since the volume of the universe is proportional to $a^3$:

$$\frac{dV}{dt} = 3HV$$

Since space is expanding, one would expect matter to become more and more dilute as time goes on. The only solution to the **steady state theory** is to postulate that new matter is constantly being created at the rate:

$$\frac{dM}{dt} = \rho \times \frac{dV}{dt}$$

keeping the density of the universe constant.

$$\frac{dM}{dt} = 3HM$$

The **rate of change of mass in the universe** is proportional to three times the product of the **Hubble constant** and the **mass** itself.

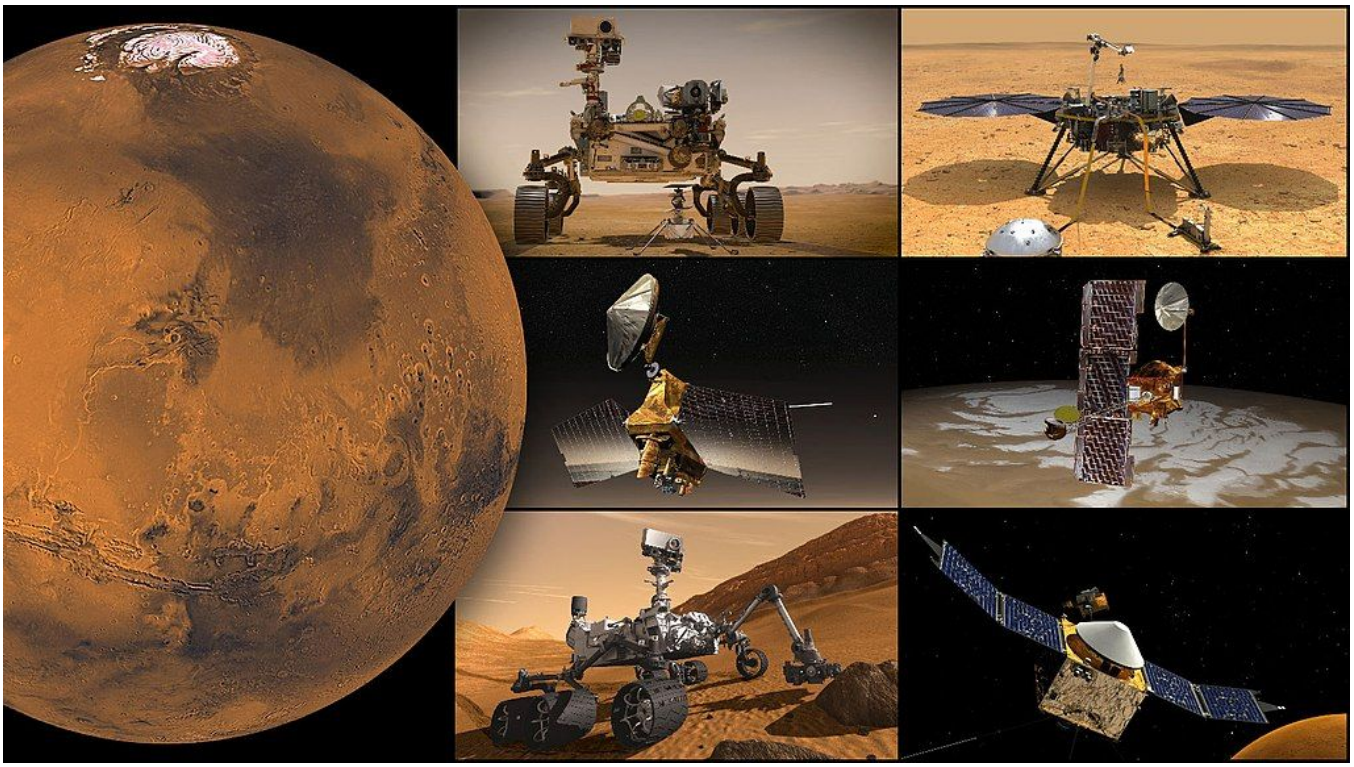


The **Steady State theory**, introduced by **Sir Fred Hoyle** in 1948 as an alternative to the **Big Bang theory**, posits a cosmological model where the universe has no beginning or end in time, continues to expand while keeping a **constant average density**, with matter constantly being generated to form new stars and galaxies at the same pace as old ones become undetectable due to their increasing distance and speed of recession. Throughout the 20th century, the **steady-state model** exerted a significant impact on the scientific community, garnering support from notable figures within the field. However, subsequent scientific advancements, including the discovery of **cosmic microwave background radiation** and the **observed distribution of light elements**, have discredited the **Steady State theory**. These pieces of evidence align more convincingly with the explanatory power of the **Big Bang theory**.

The **Planck length** is the smallest length that has physical significance in the theory of **quantum mechanics** and **quantum gravity**. It is approximately equal to $\sqrt{\frac{\hbar G}{c^3}} \approx 1.616255 \times 10^{-35}$ meters. The **Planck length** is a fundamental constant of nature and is considered to be the smallest length scale at which the **classical concepts of space and time** break down and the **laws of quantum mechanics** become dominant. At this scale, the gravitational force between two particles becomes comparable to the unpredictable forces of quantum mechanics, leading to the need for a theory that unifies quantum mechanics and general theory of relativity, like **string theory** or **loop quantum gravity**. The **Planck length** might represent the smallest distance that can be measured physically. Any effort to explore even shorter distances through higher-energy collisions could lead to the creation of **black holes.**

## Astrograph

A specialized type of telescope designed specifically for capturing images of the night sky, particularly aimed at **astronomical surveys**, **photography**, and the identification of celestial bodies like asteroids, meteors, and comets.



As of **September 28, 2021**, NASA's endeavors on **Mars** encompass a set of missions depicted in a clockwise arrangement from the upper left: the **Perseverance rover** and **Ingenuity Mars Helicopter**, the **InSight lander**, the **Odyssey orbiter**, the **MAVEN orbiter**, the **Curiosity rover**, and the **Mars Reconnaissance Orbiter**.

The **Compton Effect**, also known as **Compton scattering**, is the scattering of photons by charged particles, usually electrons. It was first described by **Arthur Holly Compton** in 1923 and demonstrated that light has both wave-like and particle-like properties. The effect results in a decrease in energy (and corresponding increase in wavelength) of the scattered photon and is a fundamental phenomenon in **quantum mechanics**. The **Compton Effect** is a well-established and widely accepted phenomenon in physics and there are no known failures of the effect. It has been confirmed experimentally numerous times and is in agreement with theoretical predictions. The effect is also in good agreement with other experimental observations and is considered to be a cornerstone of our understanding of the nature of light and its interactions with matter. That being said, the **Compton Effect** is a statistical process and individual scattering events may deviate from the predicted outcome, but the overall agreement with predictions is excellent.

**The formula for Compton scattering:**

$$\Delta\lambda = \frac{h}{m_0 c}(1-\cos\theta)$$



where $\Delta\lambda$ is the Compton shift in wavelength, the quantity $\frac{h}{m_0 c}$ is the Compton wavelength for the electron, $m_0$ is the electron rest mass and $\theta$ is the scattering angle.

- If $\Delta\lambda = \sqrt{\frac{\hbar G}{c^3}}$ = Planck length:

$$M_{Planck} = \frac{m_0}{2\pi(1-\cos\theta)}$$

- If $\theta = 90^o$:

$$M_{Planck} = \frac{m_0}{2\pi}$$

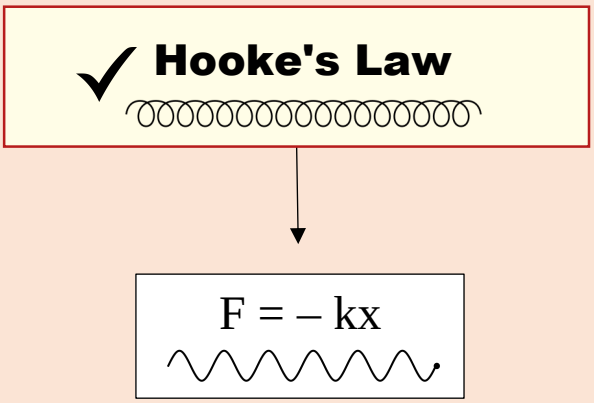
**Planck mass** is the reduced rest mass of the particle for which the Compton shift of the photon wavelength in an angle of $90^o$ is equal to the Planck length.

## ✓ The Coincidence Problem

The strength of gravity, the electromagnetic force, and the masses of elementary particles are just a few of the fundamental constants of nature that seem to be precisely tuned to allow for the existence of life. The **cosmos** would not be able to support the emergence of galaxies, stars, planets, or life as we know it if these constants were even slightly different. **For example,** stars would not be able to produce and maintain stable nuclear fusion if the **strength of gravity** were just a little bit stronger or weaker. **Chemical bonding** would not be possible if the **electromagnetic force** were slightly greater or weaker, inhibiting the synthesis of complex molecules required for life. This apparent fine-tuning has led to debates and different interpretations among scientists and philosophers. Some claim that this supports the **multiverse theory**, **in which there are countless universes with various constant values — it is not surprising that some would have values suitable for life** — while others contend that it supports the idea that there is a designer or creator who deliberately set the constants to support life. The debate continues, with no definitive answer currently available.

| Force | Relative strength |
|---|---|
| Gravity | Much weaker ↓ Much stronger |
| Weak interaction | |
| Electromagnetism | |
| Strong interaction | |

| ✓ Impulse formula | I = dp<br>**Impulse** applied on the object is equal to change in momentum of an object. |
|---|---|
| When the mass of the object is constant | I = mdv |
| When the mass of the object is variant | I = mdv + vdm |




where:

- F is the restoring force of the spring,
- k is the spring constant (a measure of the stiffness of the spring), and
- x is the displacement of the spring from its equilibrium position.
- The **negative sign** indicates that the restoring force of the spring acts in the opposite direction of the displacement of the spring from its equilibrium position. It means that when the spring is stretched or compressed, it exerts a force in the opposite direction, trying to restore itself to its equilibrium position.

Let's consider a spring with a **spring constant** of k = 20 N/m. If the spring is displaced by x = 0.1 meters from its equilibrium position, we can calculate the **restoring force of the spring** using **Hooke's Law**.

$$F = -kx$$

$$F = -(20\ \text{N/m}) \times (0.1\ \text{m})$$

$$F = -2\ \text{N}$$

Therefore, the restoring force of the spring is 2 Newtons. The **negative sign** indicates that the restoring force acts in the opposite direction of the displacement of the spring, trying to bring the spring back to its equilibrium position. **Hooke's Law** is applicable as long as the displacement is within the elastic limit of the spring. If the displacement becomes too large, the spring may no longer obey **Hooke's Law** and may undergo permanent deformation.



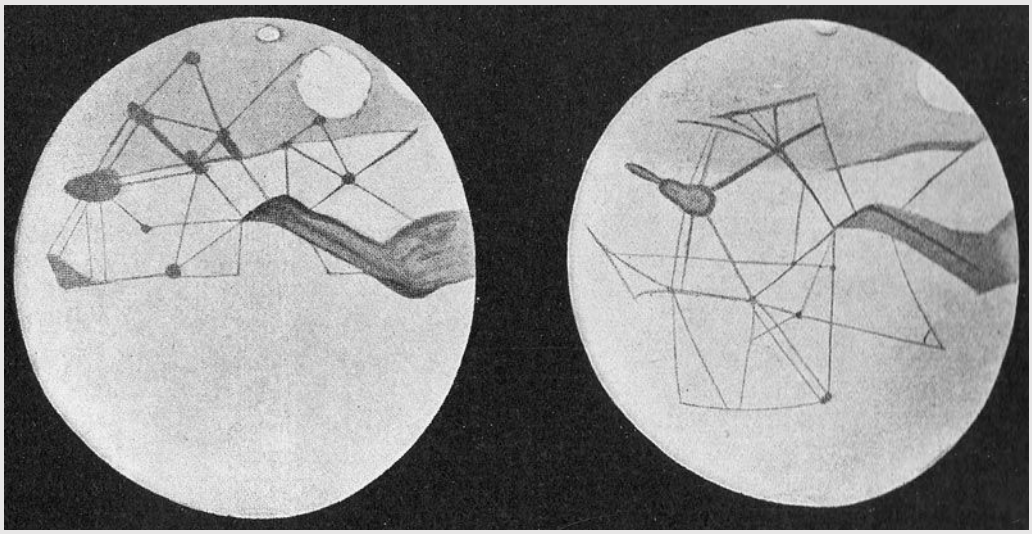


Percival Lowell.

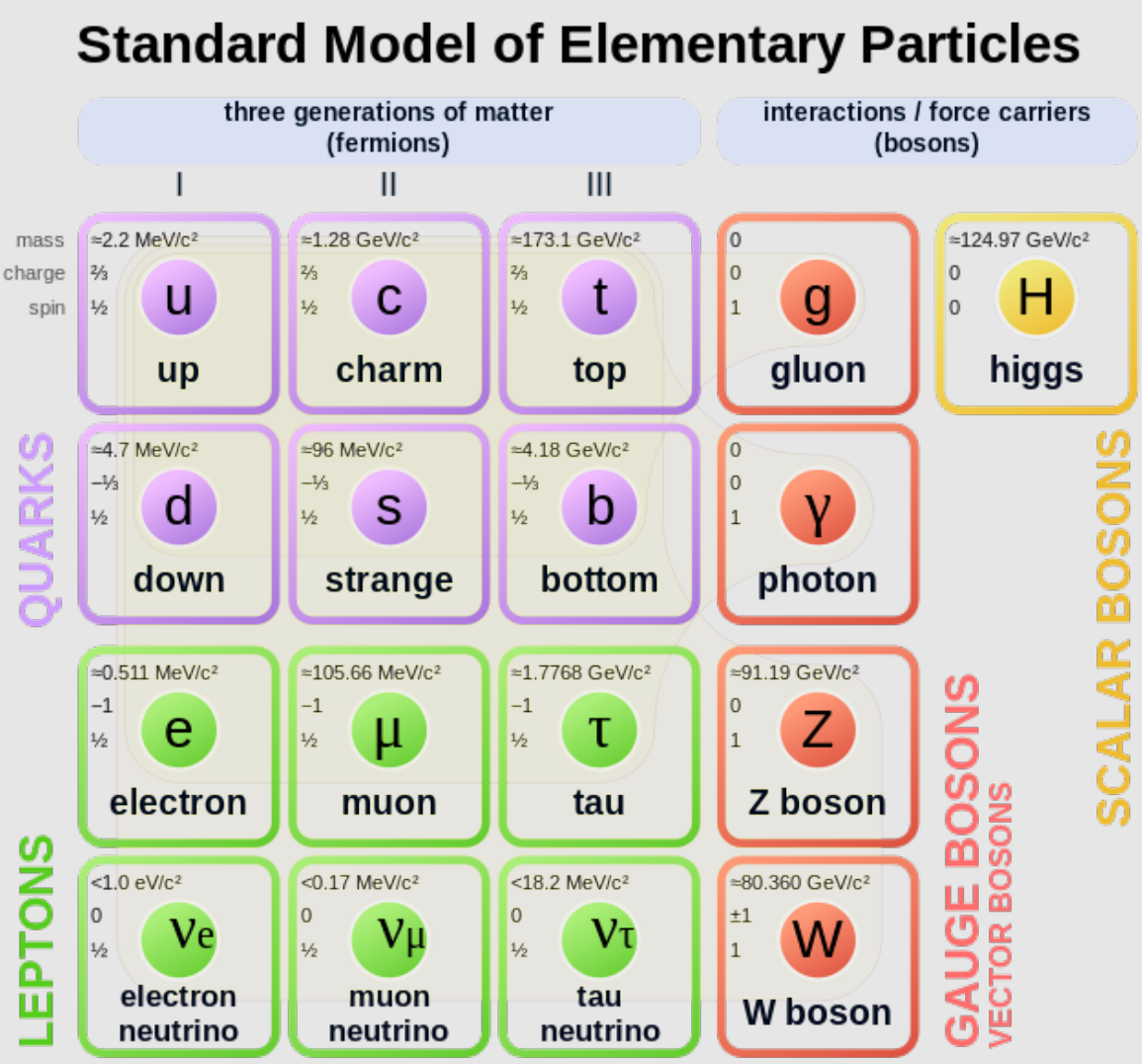
**Percival Lowell** (1855−1916) was an American businessman, author, and astronomer best known for his observations and theories about Mars. He was born into a wealthy Boston family and attended **Harvard University**, but left before completing his degree. He later traveled extensively in the Far East and wrote several books about his experiences. Lowell became interested in astronomy after viewing the 1874 transit of Venus. In 1894, he founded the **Lowell Observatory** in Flagstaff, Arizona, where he conducted extensive studies of the planets, particularly Mars. He claimed to have observed a network of canals on the **Martian surface**, which he believed were evidence of an advanced civilization. He wrote several books on the subject, including "**Mars**" (1895) and "**Mars and its Canals**" (1906). **Lowell's theories** about the canals of Mars were controversial and eventually discredited by other astronomers, who found no evidence to support his claims. Nevertheless, Lowell's observations and writings were influential in popularizing the idea of intelligent life on other planets and stimulating public interest in astronomy. Lowell also made important contributions to the study of the outer solar system. In 1906, he predicted the existence of a ninth planet beyond Neptune, which he called "**Planet X.**" The search for **Planet X** continued after Lowell's death, and ultimately led to the discovery of **Pluto** in 1930, though it was later determined that Pluto was not the same planet **Lowell** had predicted. Lowell died in 1916, and the Lowell Observatory continues to be an important center for astronomical research and education.



**Percival Lowell in 1914, observing Venus in the daytime with the 24-inch (61 cm) Alvan Clark & Sons refracting telescope at Flagstaff, Arizona**



**Martian canals** depicted by **Percival Lowell**



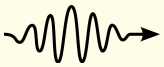

**Elementary particles of the Standard Model**

✓ **If the mass of the star < 1.4 solar masses**



- Electrons prevent further collapse.
- The core will thus continue to collapse and form a white dwarf.

✓ **If the mass of the star > 1.4 solar masses but mass < 3 solar masses**



- Electrons + protons combine to form neutrons.
- Neutrons prevent further collapse.
- The core will thus continue to collapse and form a neutron star.

✓ **If the mass of the star > 3 solar masses**



- Gravity wins! Nothing prevents collapse.
- The core will thus continue to collapse and form a black hole.

**Electrons** cannot be accelerated by cyclotron because the mass of the electron is so small (**0.511 MeV/$c^2$**) that the electron attain very large energy in small interval of time and hence get out of step very quickly with the oscillating electric field.



$$\text{Half-life} = \frac{0.693}{\text{Decay constant}}$$



Longer half-life of nucleus → Slow Radioactive Decay.

Shorter half-life of nucleus → Fast Radioactive Decay.

**".. Physics at the atomic and subatomic level ..."**

... **Weird things are possible:**

- ✓ **Energy is quantized (E = nhu).**
- ✓ **Momentum is quantized (L = nħ).**
- ✓ **Charge is quantized (Q = ne).**



An image of **Ganymede** captured by the **Juno spacecraft** during its **34th perijove pass**.

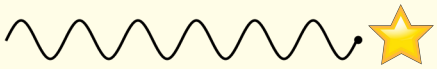
The largest moon of Jupiter and is also the largest moon in the entire solar system. It's even larger than the planet Mercury.

✓ **KE = eV**

When accelerated by the same potential, both an electron and a proton gain a same amount of kinetic energy, let's say **KE**. The de Broglie wavelengths of these particles are:

$$\lambda_e = \frac{h}{\sqrt{2m_e\,KE}} \qquad \lambda_p = \frac{h}{\sqrt{2m_p\,KE}}$$

**For equal kinetic energies, a lighter particle possess larger wavelength**



✓ **D'Alembert's principle**

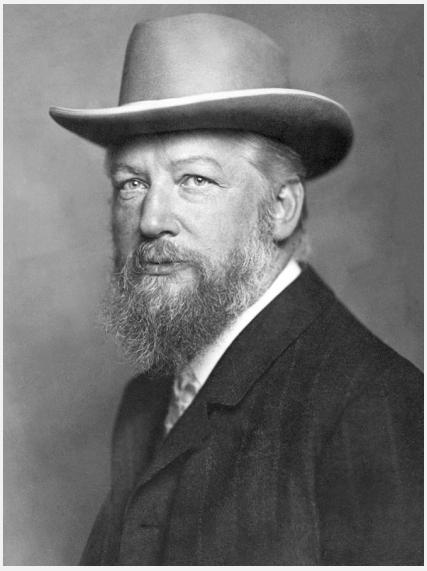
A fundamental principle in classical mechanics named after the **French mathematician** and **physicist**, **Jean le Rond d'Alembert**. It states that for a system of particles in equilibrium, the sum of the forces acting on each particle, as well as the sum of the products of the masses of the particles and their respective accelerations, is equal to zero. Mathematically, this **principle** can be expressed as:

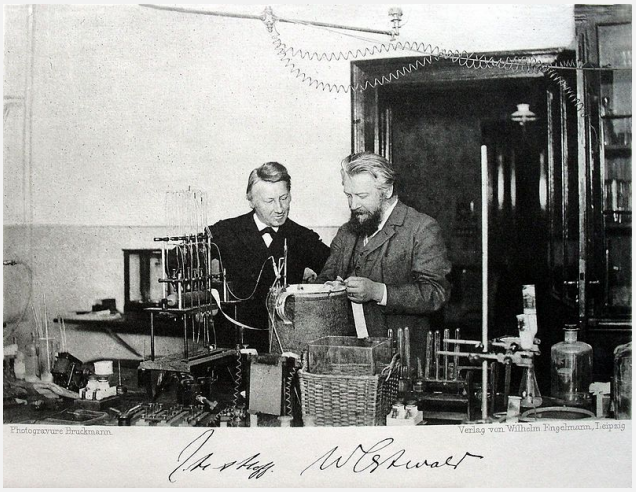
$$\sum F = \sum(m_i \times a_i) = 0$$

where $\sum F$ is the sum of the forces acting on each particle in the system, $\sum(m_i \times a_i)$ is the sum of the products of the masses of the particles and their respective accelerations, and the subscript i denotes each individual particle in the system. **D'Alembert's principle** is widely used in the study of mechanics and has numerous applications in fields such as engineering, physics, and mathematics.



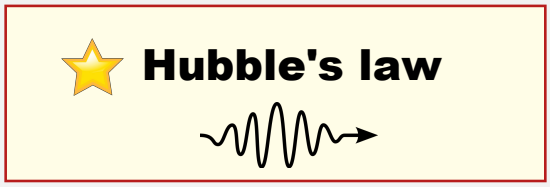
✓ Jean le Rond d'Alembert






Jacobus Henricus van 't Hoff and Wilhelm Ostwald in the laboratory

**Wilhelm Ostwald** was a German chemist who made significant contributions to the fields of physical chemistry and chemical engineering. He was born on September 2, 1853, in Riga, which is now part of Latvia, and died on April 4, 1932, in his home in Grossbothen, Germany. **Ostwald** is known for his work on catalysis, chemical equilibria, and reaction rates. He was awarded the **Nobel Prize in Chemistry in 1909** for his work on catalysis, chemical equilibria, and reaction rates. In particular, he developed the concept of catalysis as a surface phenomenon and studied the effects of temperature and concentration on chemical reactions. Ostwald was also a pioneer in the field of chemical engineering, applying his understanding of chemical reactions to the development of industrial processes. He was a strong advocate for the use of science in industry and believed that scientific principles should be applied to the development of practical applications. In addition to his scientific contributions, **Ostwald** was also a prominent figure in the intellectual and cultural life of his time. He was a member of the **German Academy of Sciences** and was involved in the founding of the German Chemical Society. He was also an advocate for international cooperation and was involved in the founding of the International Association of Chemical Societies. Overall, **Ostwald** was a key figure in the development of modern physical chemistry and chemical engineering, and his contributions continue to influence these fields today.




**Hubble's law** is a fundamental principle in cosmology that describes the relationship between the distance to a galaxy and its velocity relative to us. This law is based on observations made by astronomer **Edwin Hubble** in the 1920s, and it is expressed mathematically as follows:

$$v = H \times d$$

where v is the velocity of the galaxy (in km/s), d is its distance from us (in megaparsecs), and H is the Hubble constant (in km/s/Mpc). The **Hubble constant** is a measure of the rate at which the universe is expanding. To understand how this equation works, let's look at an example. Suppose we observe a galaxy that is **100 megaparsecs** away from us, and it is moving away from us at a velocity of **10,000 km/s**. We can use **Hubble's law** to determine the value of the Hubble constant:

$$H = \frac{v}{d} = \frac{10{,}000\ \text{km/s}}{100\ \text{Mpc}} = 100\ \text{km/s/Mpc}$$

This means that for every **megaparsec** of distance, the galaxy is moving away from us at a rate of **100 km/s**. We can also use this equation to estimate the **age of the universe**, since the expansion rate has changed over time. By extrapolating backwards, we can determine that the universe began expanding about **13.8 billion years ago**.

# Beer-Lambert Law



The **Beer-Lambert Law** is a fundamental principle in spectroscopy and describes the relationship between the absorbance of a sample, the concentration of the absorbing species, and the path length of the sample. The law states that the **absorbance of a sample** is proportional to the concentration of the absorbing species and the path length of the sample:

$$A = \varepsilon \times C \times L$$

where A is the absorbance, ε is the **molar absorptivity** (a constant that depends on the properties of the absorbing species and the wavelength of light used), C is the concentration of the absorbing species, and L is the path length of the sample (the distance light travels through the sample). Let's consider an example. Suppose we have a solution of **0.1** Molar concentration of a solution that has a **molar absorptivity** of **100 L/mol/cm** at a wavelength of **500 nm**. We measure the absorbance of the solution using a **cuvette** with a path length of 1 cm. **The Beer-Lambert Law** can be used to calculate the absorbance:

$$A = \varepsilon \times C \times L$$

$$A = (100\ \text{L/mol/cm}) \times (0.1\ \text{mol/L}) \times (1\ \text{cm})$$

$$A = 10$$

This means that the **absorbance of the solution** is **10** at **500 nm**. We can also use the **Beer-Lambert Law** to calculate the concentration of an unknown solution given its absorbance and the molar absorptivity of the solution:

$$C = \frac{A}{\varepsilon \times L}$$

Suppose we measure an absorbance of **0.5** for an unknown solution with the same molar absorptivity and path length as the previous example. We can calculate the concentration of the unknown solution as:

$$C = \frac{0.5}{100\ \text{L/mol/cm} \times 1\ \text{cm}} = 0.005\ \text{M}$$

Therefore, the concentration of the unknown solution is **0.005** M.



Pierre Bouguer

**Pierre Bouguer** (1698−1758) was a French mathematician, physicist, and astronomer who made important contributions to the study of optics, hydrodynamics, and geodesy. He is best known for his work on the attenuation of light in the atmosphere and his development of the concept of **"specific gravity."** In 1729, **Bouguer** published a book entitled **"La Figure de la Terre,"** in which he described his measurement of the length of a degree of arc of the meridian in Peru. He used this measurement to calculate the shape of the Earth and showed that it was an oblate spheroid, meaning that it bulges at the equator and is flattened at the poles. **Bouguer** is also known for his work on the attenuation of light in the atmosphere, which he studied during a voyage to Peru in 1735. He found that the intensity of light passing through the atmosphere decreased exponentially with increasing thickness of the atmosphere. He also discovered that the amount of light absorbed by the atmosphere depended on the wavelength of the light, which laid the foundation for the **Beer-Lambert Law**. In addition to his work on optics and geodesy, **Bouguer** made significant contributions to the study of hydrodynamics, including the development of a theory of fluid flow and the measurement of the velocity of water in open channels. **Bouguer** was a member of the French Academy of Sciences and was awarded the prestigious **Copley Medal** by the **Royal Society of London** in 1748 for his contributions to the study of optics. His work laid the foundation for the development of modern photometry and his name is still used in the measurement of light attenuation in the atmosphere, with the term **"Bouguer extinction"** referring to the amount of light absorbed by the atmosphere.



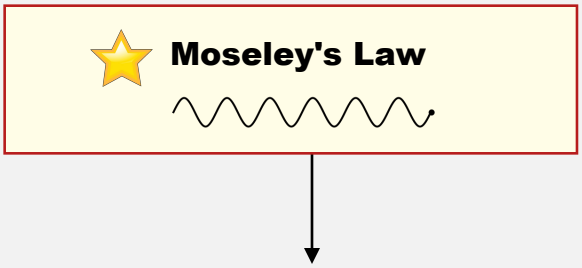
# Drake Equation

The **Drake Equation** is a mathematical equation used to estimate the number of potential extraterrestrial civilizations in the Milky Way galaxy that could communicate with us. It was developed by astronomer **Frank Drake** in 1961 as a way to stimulate scientific discussion about the likelihood of intelligent life in the universe. The equation takes into account several factors that are necessary for the development of intelligent life and the likelihood of communicating with such life. The equation is as follows:

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

where **N** is the estimated number of civilizations that could communicate with us, **R*** is the rate of star formation in the galaxy, $\mathbf{f_p}$ is the fraction of stars with planets, $n_e$ is the number of planets per star with conditions suitable for life, $\mathbf{f_l}$ is the fraction of suitable planets where life actually emerges, $\mathbf{f_i}$ is the fraction of emerging life that becomes intelligent, $\mathbf{f_c}$ is the fraction of intelligent civilizations that develop the ability to communicate, and **L** is the length of time these civilizations survive. Each of these factors is uncertain, and estimating values for them can lead to a wide range of possible values for **N**. Despite its uncertainties, the **Drake Equation** remains a useful tool for understanding the factors that influence the existence of extraterrestrial civilizations and stimulating discussion about the search for intelligent life in the universe.

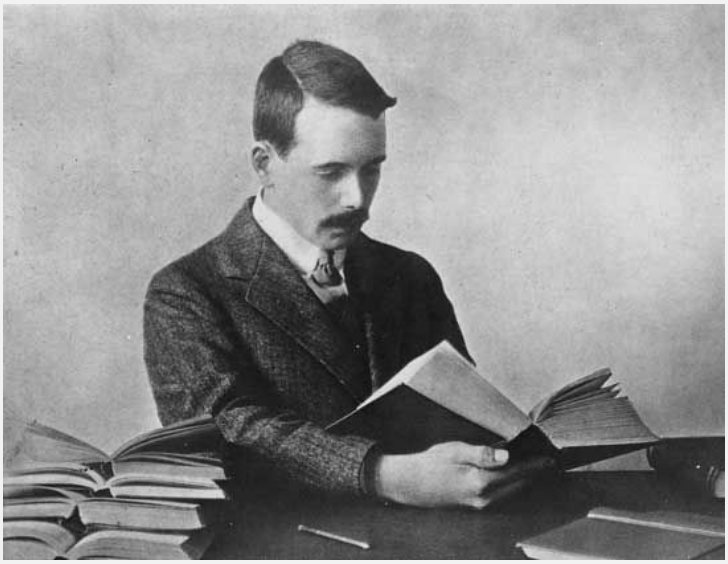
| Helmholtz free energy (A) | Gibbs free energy (G) |
| --- | --- |
| $A = U - TS$ | $G = H - TS$ |
| The difference between the internal energy of a system **(U)** and the energy that is unavailable to do work **(TS)** | The difference between the enthalpy of a system **(H)** and the energy that is unavailable to do work **(TS)** |




**Moseley's Law**, also known as **Moseley's periodic law**, is a scientific principle that describes the relationship between the wavelength of an X-ray and the atomic number of the element it is interacting with. The law was discovered by British physicist **Henry Moseley** in 1913 and was an important development in the understanding of the periodic table of elements. **Moseley's Law** states that the square root of the frequency of the characteristic X-ray emitted by an element is proportional to its atomic number. Mathematically, this can be expressed as:

$$\sqrt{\upsilon} \propto Z$$

where $\upsilon$ is the frequency of the X-ray and Z is the atomic number of the element. The law is significant because it provides a method for determining the atomic number of an element based on its X-ray spectrum. It also helped to explain the periodicity of the elements in the periodic table and led to the concept of atomic number as the fundamental organizing principle of the elements.



Moseley in 1914

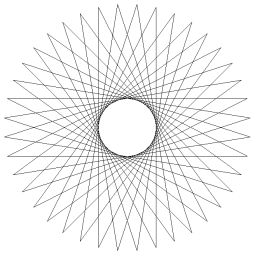


Moseley in the Balliol-Trinity Laboratories in 1910

## The Life of a Star:

"More mass
More pressure and temperature
Faster Fusion
Shorter life"





"Less mass
Less pressure and temperature
Slower Fusion
Longer life"

## String Theory

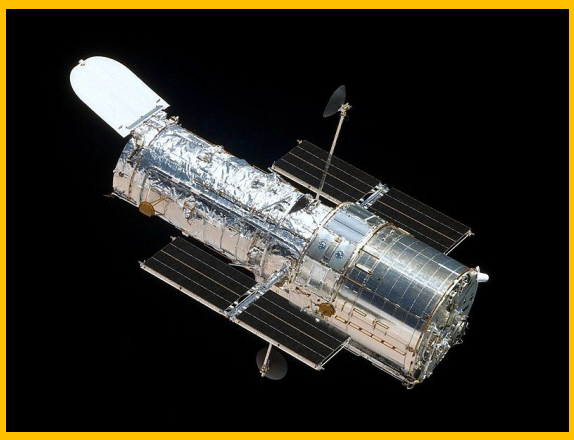
(A theory that tries to adjust / harmonize / reconcile General Relativity and Quantum mechanics)

Different vibrations → Different particles.
String combinations → Particle interactions.

## MATTER UNDER EXTREME CONDITIONS

Nuclei + heat + pressure → quark-gluon plasma

**Pluto is an extremely far-off object from the Sun, making it difficult to see it properly from Earth. The Hubble Space Telescope, however, was able to observe it and identify its two new moons, Hydra and Nix.**



The Hubble Space Telescope

The Moon was only 22,500 kilometers from the Earth when it formed. However, it is currently about 384,000 kilometers away. Also discovered by scientists is the Moon's annual distance from the Earth increasing by almost 3.8 cm (the width of a thumbnail).

**Weak nuclear forces + Maxwell equations → Electro weak theory.**

Electro weak theory + Quantum Chromodynamics (QCD) → Standard Model of particle physics.

**Standard Model of particle physics** → explains everything except gravity

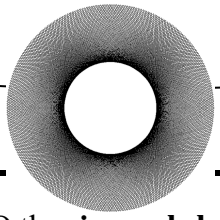
**Hydrogen atom:** Diameter about a Billionth of an inch.

**Electron:** Diameter at least 1000 times smaller than that of proton.

**Proton:** Diameter about 60,000 times smaller than H atom.

**Probability distribution is the only way to locate an electron in an atom.**

At Planck length $\sqrt{\frac{\hbar G}{c^3}}$ , space-time becomes "**foamy**," with tiny bubbles and wormholes appearing and disappearing into the vacuum.



Because $dM = \frac{k}{8\pi} dA + \Omega dJ + \Phi dQ$ the **size and shape of the black hole** depends only on its mass, charge and rate of rotation, and not on the nature of the star that had collapsed to form it.

**Just like a dozen is 12 things, a mole is simply Avogadro's number of particles.**

Wavelength of UV radiation < Wavelength of IR radiation < Wavelength of microwave radiation



**Molecule dissociates (when it absorbs UV radiation).**

**Molecule vibrates (when it absorbs IR radiation).**

**Molecule rotates (when it absorbs microwave radiation).**

The entire **electromagnetic spectrum** —from radio waves to gamma rays, most of the light in the universe — resembles nothing but **transverse waves** of energy $E = h\upsilon = \frac{hc}{\lambda}$, which in turn are vibrating **Maxwell force fields** differing only in their wavelength $\lambda = \frac{h}{p}$.

**Fibonacci numbers – 1, 1, 2 , 3, 5, 8, 13, 21, 34, 55, 89, 144...**

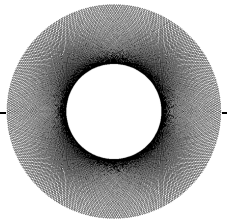
- Each number is the sum of the previous two.
- The ratio between the numbers = 1.618034 (golden ratio).
- From pinecones to the Hurricane Sandy, Fibonacci reflects various patterns found in nature.

**The paths of anything you throw have the same shape, called an upside-down parabola.**



When we observe how objects move around in gravitationally curved trajectories in space, we discover another recurring shape: **the ellipse**

Neutrons have a mass of **939.56 MeV**. If the mass of a neutron was a seventh of a percent more than it is, stars like most of those we can see would not have existed. If the neutron mass was 0.085% less than it is, the Universe would have been full of neutrons and nothing else.



If we cut the surface of a sphere up into faces, edges and vertices, and let F be the number of faces, E the number of edges and V the number of vertices, we will always get:

$$V - E + F = 2$$

All material particles have properties such as charge and spin. Space itself has properties such as dimensions. These properties are purely mathematical.

**The Gas laws deal with how gases behave with respect to pressure, volume, temperature ...**

**Boyle's law:** Volume and pressure are inversely proportional.

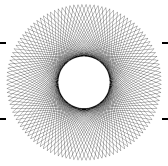
**Charles' law:** Volume is proportional to temperature.

**Pressure law:** Pressure is proportional to temperature.



**All three combined:**

$$\frac{PV}{T} = \text{constant}$$

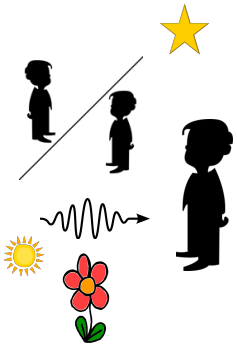


- **Grand unification energy** → The energy above which the electro-magnetic force, weak force, and strong force become indistinguishable from each other.
- The distance — and the path — that a body travels, looks different to different observers.
- Faint light means fewer photons.
- **Wormholes** provide shortcuts between distant points in space.
- In more than **three spatial dimensions**, planetary orbits would be unstable and planets would either fall into the sun or escape its attraction altogether.

Because:

$$\frac{E}{B} = c$$

- Electric and magnetic fields turn into each other in a wave like motion, creating an **electromagnetic field** that travels at the speed of light.



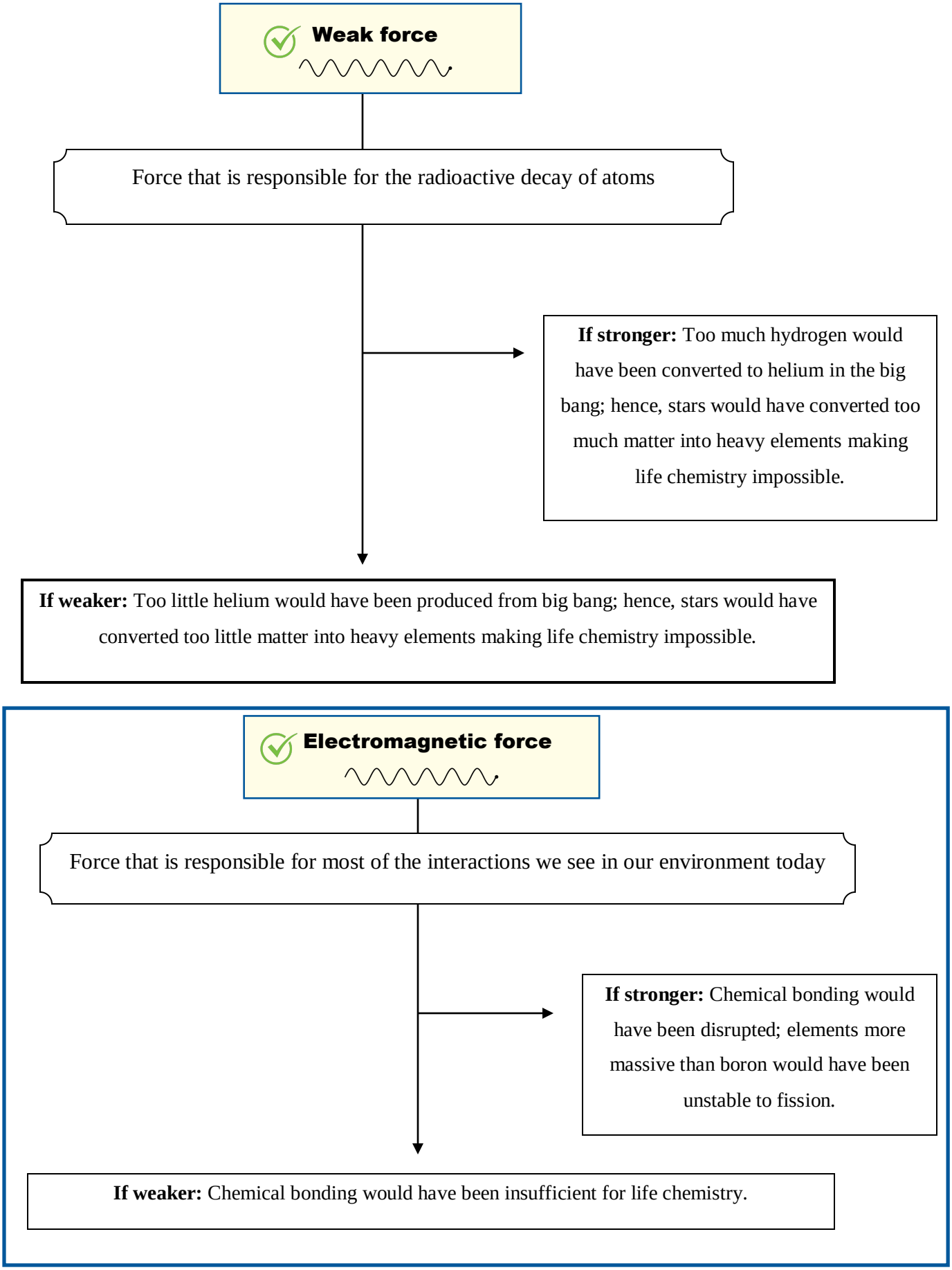
- The **CPT theorem** states that the **laws of physics** are invariant under the combined operations of **charge conjugation** (C), **parity reversal** (P), and **time reversal** (T). The **CPT theorem** has been extensively tested in various experiments, and no violations have been observed to date. It plays a crucial role in establishing the **principles of quantum field theory**, ensuring that the laws of physics remain consistent and symmetric under different transformations.
- **Speed of light** is the limiting velocity in the universe, unaffected by the movement of its source and independent of all observers.
- **Fractals** make up **many aspects of our world**, included the leaves of ferns, tree branches, the branching of neurons in our brain, and coastlines.
- Bees build their hive using a tessellation of **hexagons**.
- **Concentric Circles in Nature:** A common example is in the ripples of a pond when something hits the surface of the water.

## Strong force

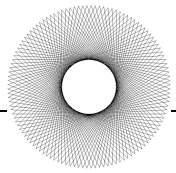
Force that is responsible for binding together the fundamental particles of matter to form larger particles

**If stronger:** No hydrogen would have formed; atomic nuclei for most life-essential elements would have been unstable; thus, there would have been no life chemistry.

**If weaker:** No elements heavier than hydrogen would have formed: again, no life chemistry.


Weak force
Force that is responsible for the radioactive decay of atoms
If stronger: Too much hydrogen would have been converted to helium in the big bang; hence, stars would have converted too much matter into heavy elements making life chemistry impossible.
If weaker: Too little helium would have been produced from big bang; hence, stars would have converted too little matter into heavy elements making life chemistry impossible.
Electromagnetic force
Force that is responsible for most of the interactions we see in our environment today
If stronger: Chemical bonding would have been disrupted; elements more massive than boron would have been unstable to fission.
If weaker: Chemical bonding would have been insufficient for life chemistry.

c = **299,792,458 meters per second** – serves as the single limiting velocity in the universe, being an upper bound to the propagation speed of signals and to the speeds of all material particles.



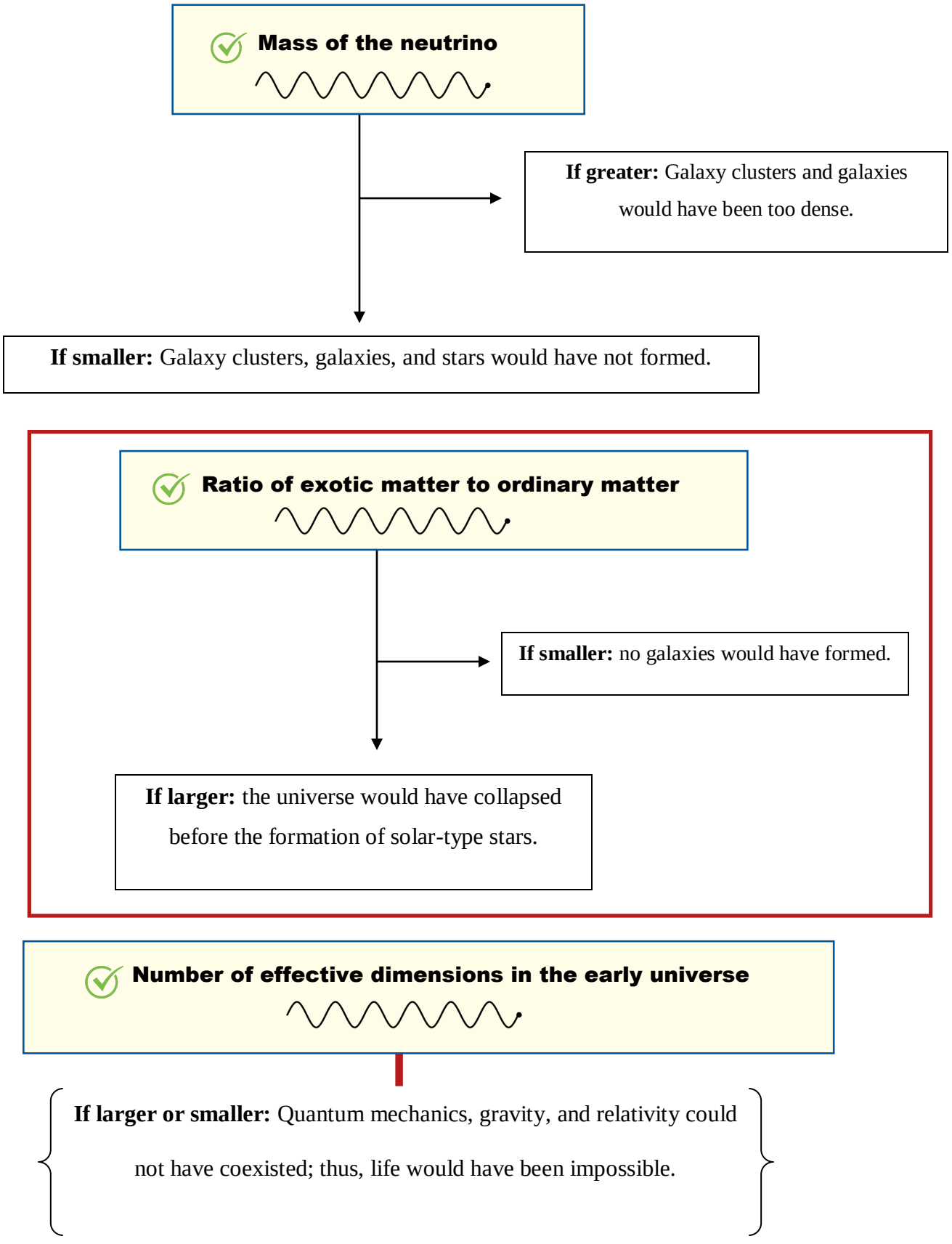
## Ratio of electromagnetic force to gravitational force

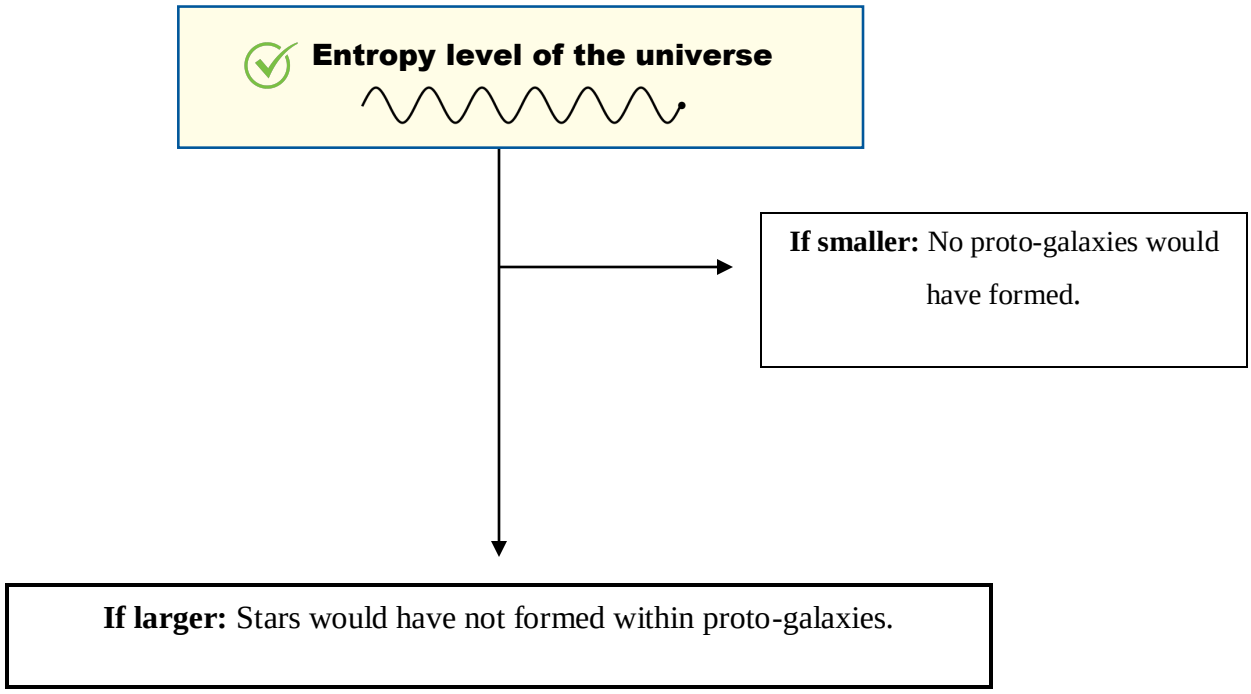
**If smaller:** All stars would have been at least 20% less massive than the sun, thus incapable of producing heavier elements.

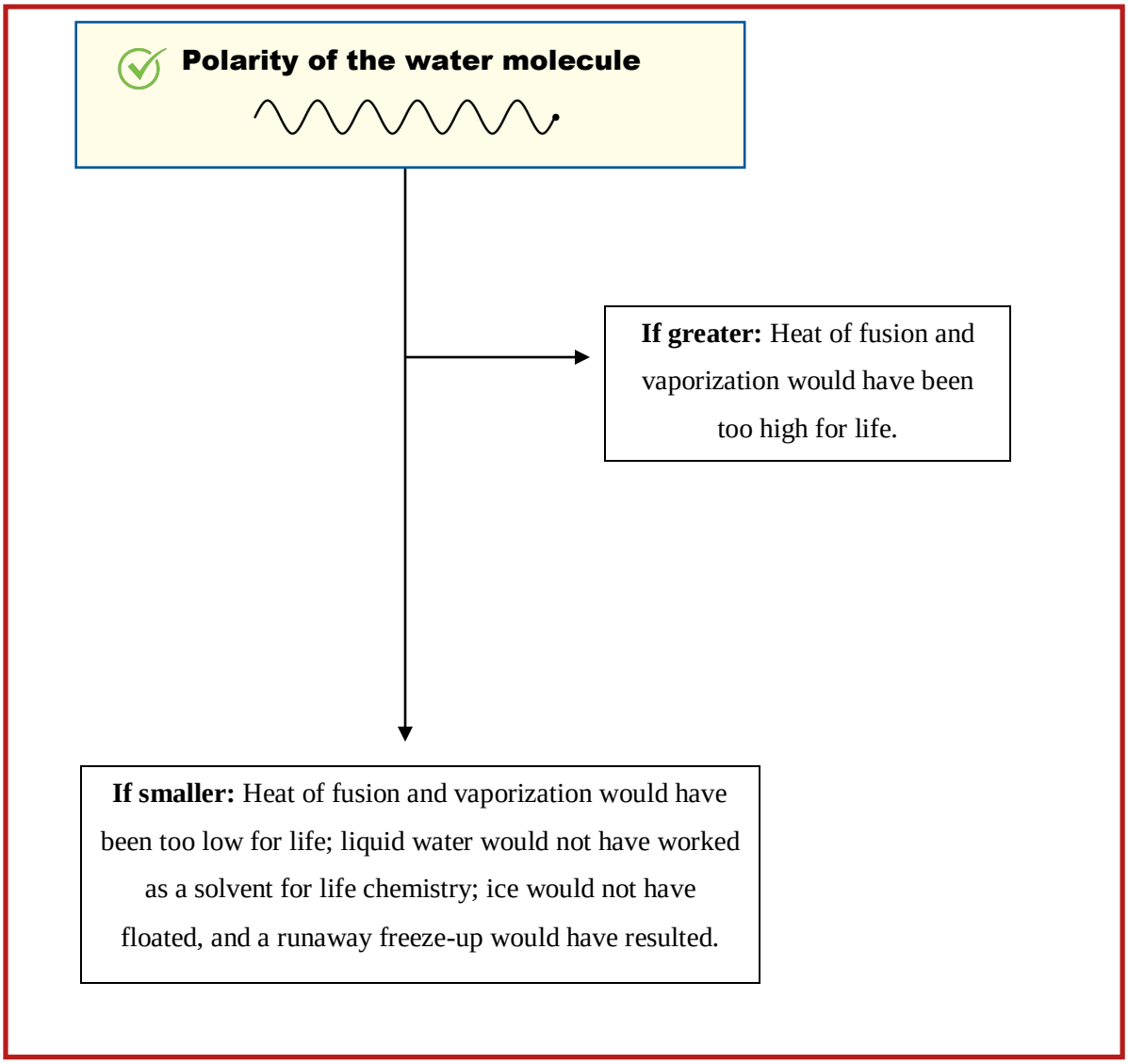
**If larger:** All stars would have been at least 40% more massive than the sun; hence, stellar burning would have been too brief and too uneven for life support.

## Ratio of electron to proton mass

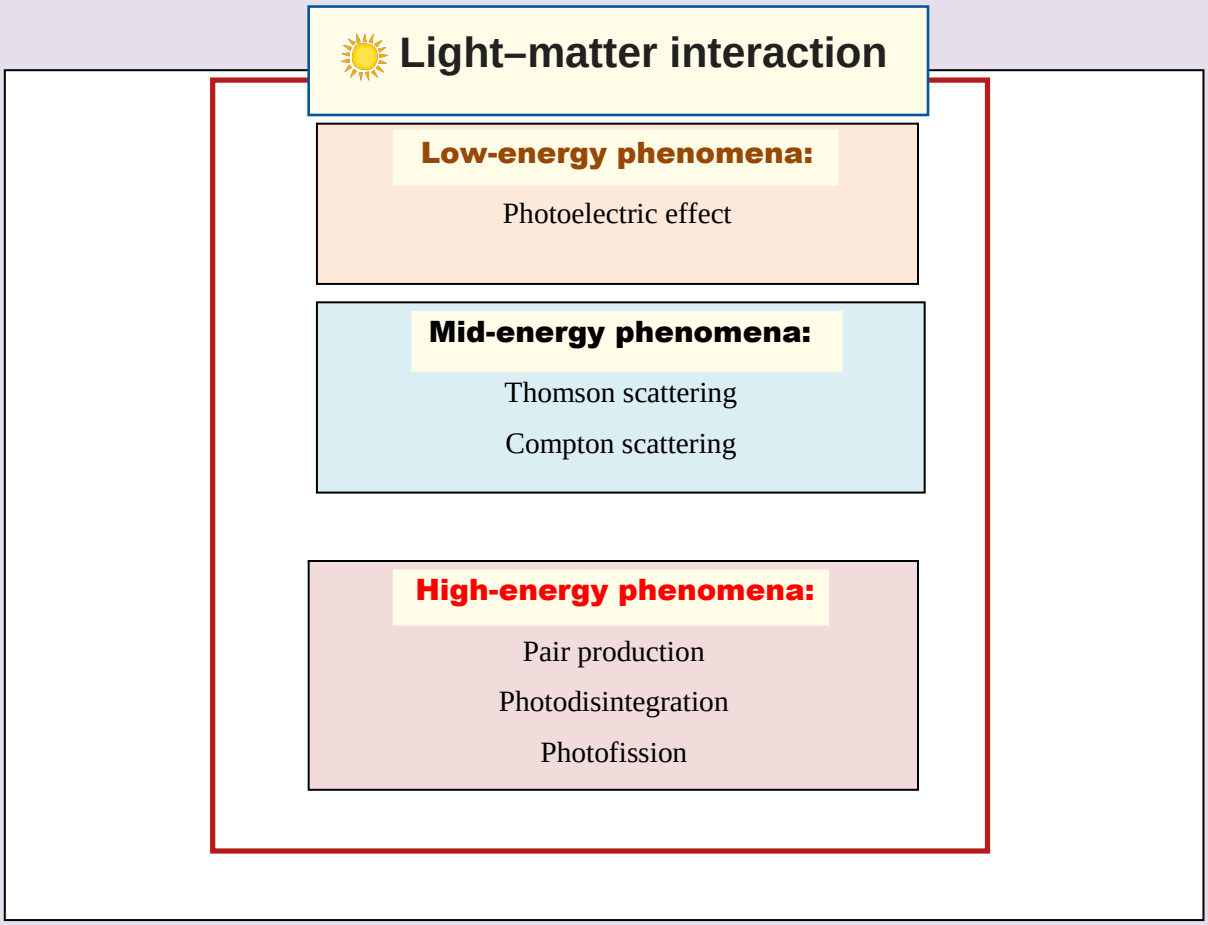
**If larger or smaller:** Chemical bonding would have been insufficient for life chemistry.

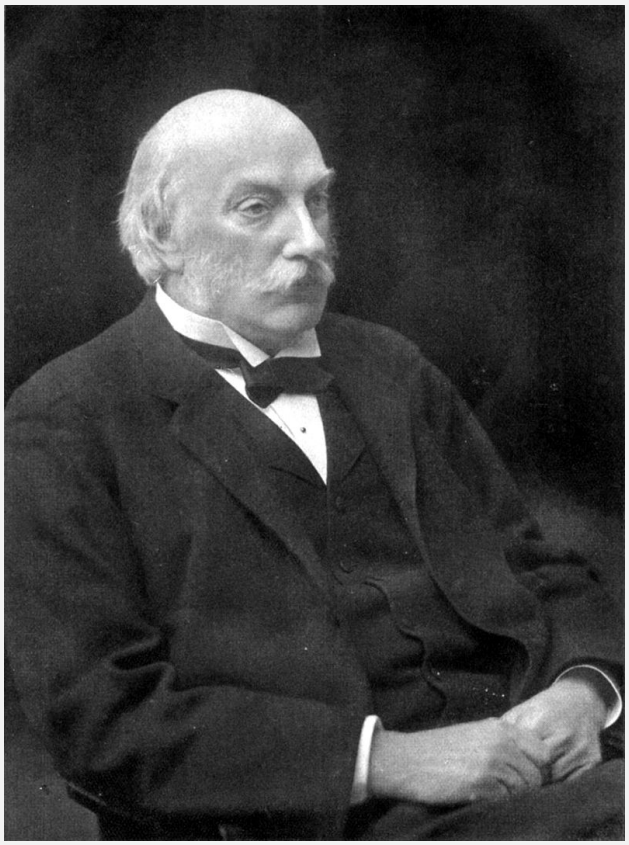

Mass of the neutrino
If greater: Galaxy clusters and galaxies would have been too dense.
If smaller: Galaxy clusters, galaxies, and stars would have not formed.
Ratio of exotic matter to ordinary matter
If smaller: no galaxies would have formed.
If larger: the universe would have collapsed before the formation of solar-type stars.
Number of effective dimensions in the early universe
If larger or smaller: Quantum mechanics, gravity, and relativity could not have coexisted; thus, life would have been impossible.

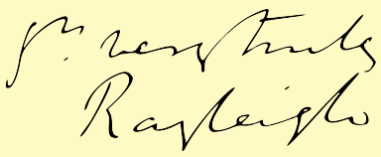

Entropy level of the universe
If smaller: No proto-galaxies would have formed.
If larger: Stars would have not formed within proto-galaxies.


Polarity of the water molecule
If greater: Heat of fusion and vaporization would have been too high for life.
If smaller: Heat of fusion and vaporization would have been too low for life; liquid water would not have worked as a solvent for life chemistry; ice would not have floated, and a runaway freeze-up would have resulted.

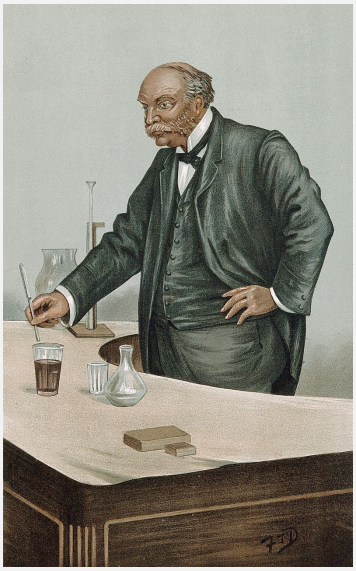
**String theory** is a theoretical framework in physics that tries to describe the fundamental nature of matter and energy in the universe. It proposes that the basic building blocks of the universe are not point-like particles but **one-dimensional "strings"**. These strings vibrate at different frequencies, giving rise to different fundamental particles such as quarks, electrons, and photons. The theory also postulates the existence of extra dimensions beyond the three dimensions of space and one of time that we observe in our everyday lives. The number of dimensions varies in different versions of the theory, but typically ranges from ten to twenty-six. In addition to providing a more comprehensive and unified explanation of the forces of nature, string theory also has the potential to resolve some of the **biggest mysteries of physics**, such as the discrepancy between quantum mechanics and general relativity, and the nature of dark matter and dark energy. However, despite its theoretical elegance, **string theory** is still a developing field and has not yet been experimentally confirmed. It remains one of the most actively researched and debated topics in physics today.



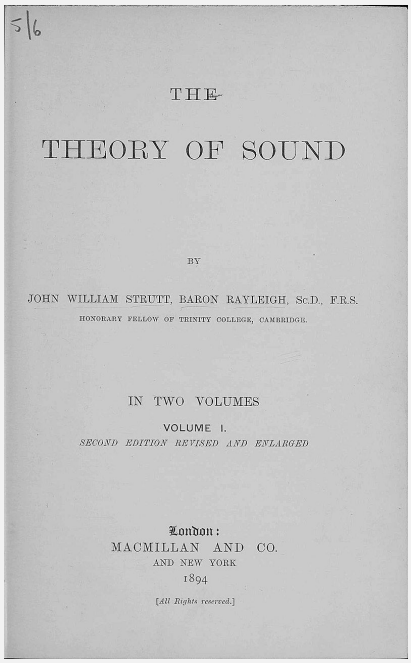




**Rayleigh scattering** is a phenomenon in which light is scattered by small particles in the atmosphere, such as air molecules or small dust particles. The scattering occurs when the particles are much smaller than the wavelength of the incident light. It is named after the British scientist **Lord Rayleigh**, who first described this phenomenon in the late 19th century. **Rayleigh scattering** is responsible for the blue color of the sky and the reddening of the sun during sunrise and sunset. This is because the shorter-wavelength blue light is more likely to be scattered in all directions, while the longer-wavelength red light is less likely to be scattered and can pass through the atmosphere more easily. **The intensity of the scattered light** is **proportional to the fourth power of the frequency of the incident light.** This means that blue light is scattered much more than red light, which is why the sky appears blue during the day.



**Caricature of Lord Rayleigh in the London magazine Vanity Fair, 1899**



THE

THEORY OF SOUND

BY

JOHN WILLIAM STRUTT, BARON RAYLEIGH, Sc.D., F.R.S.

HONORARY FELLOW OF TRINITY COLLEGE, CAMBRIDGE.

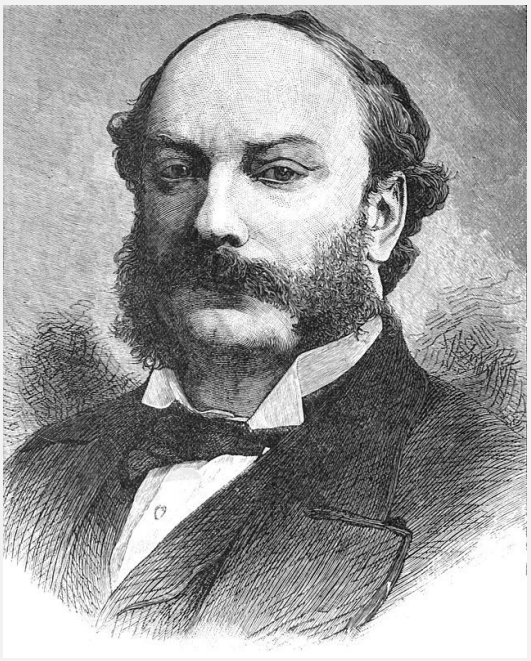
IN TWO VOLUMES

VOLUME I.

*SECOND EDITION REVISED AND ENLARGED*

London:
MACMILLAN AND CO.
AND NEW YORK
1894

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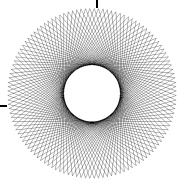


The **Theory of Sound** is a book written by British physicist and mathematician **Lord Rayleigh (John William Strutt)** in 1894. It is a comprehensive study of the physical properties of sound, including its production, propagation, and perception. The book is divided into two volumes. The **first volume** covers the mathematical and physical principles of sound, including vibrations, waves, and resonance. It also discusses the properties of musical sounds, such as pitch, timbre, and harmony. The **second volume** focuses on the practical applications of sound, including the design of musical instruments, the acoustics of rooms and auditoriums, and the use of sound in telegraphy and telephony. **The Theory of Sound** was a groundbreaking work in the field of acoustics and has had a profound impact on the study and understanding of sound. It remains a classic text in the field and is still widely referenced today.

## Energy budget of the universe:

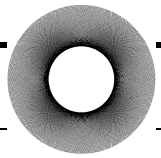
### ✓ Billion Years ago (when the Universe was 380,000 years old):

- Dark Matter: 63%
- Neutrinos: 10%
- Photons: 15%
- Ordinary Matter: 12%



### ✓ Today:

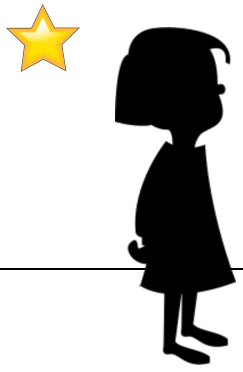
- Dark Matter: 23 %
- Dark Energy: 73%
- Ordinary Matter: 4%
- Out of 4% we only make up 0.03% of the ordinary matter.



**Total angular momentum = spin angular momentum + orbital angular momentum**

$$I = S + L$$

- For nuclei of odd mass number, I is an odd multiple of $\frac{\hbar}{2}$
- For nuclei of even mass number, I is an even multiple of $\frac{\hbar}{2}$



## Faber–Jackson relation

**Luminosity of elliptical galaxy** $\propto$ (velocity dispersion of the stars in an elliptical galaxy)$^4$

This relation implies that galaxies with **higher velocity dispersions** (indicating greater internal motion of stars) will have significantly **higher luminosities** (brightness) than galaxies with lower velocity dispersions.

**Flux-weighted gravity** $= \dfrac{\text{Stellar surface gravity}}{(\text{Effective temperature})^4}$

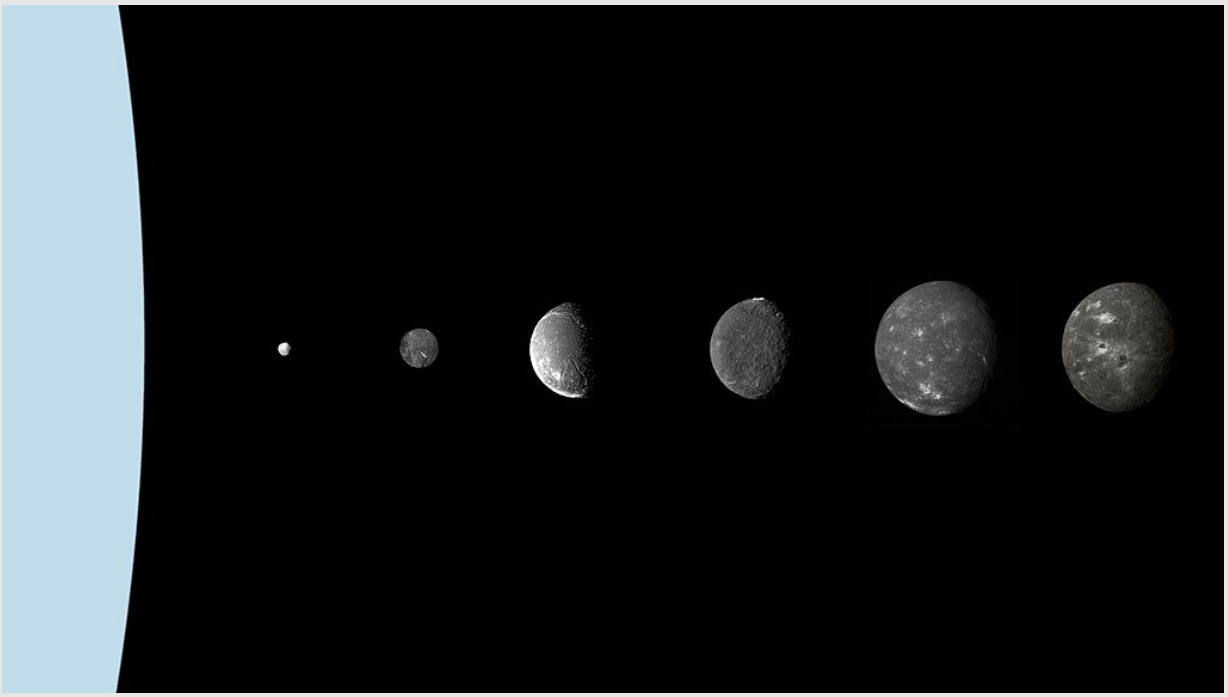
**Quadrupole moment** $\sim$ source mass $\times$ (source size)$^2$

A measure of how far from spherically symmetric a radiating source is

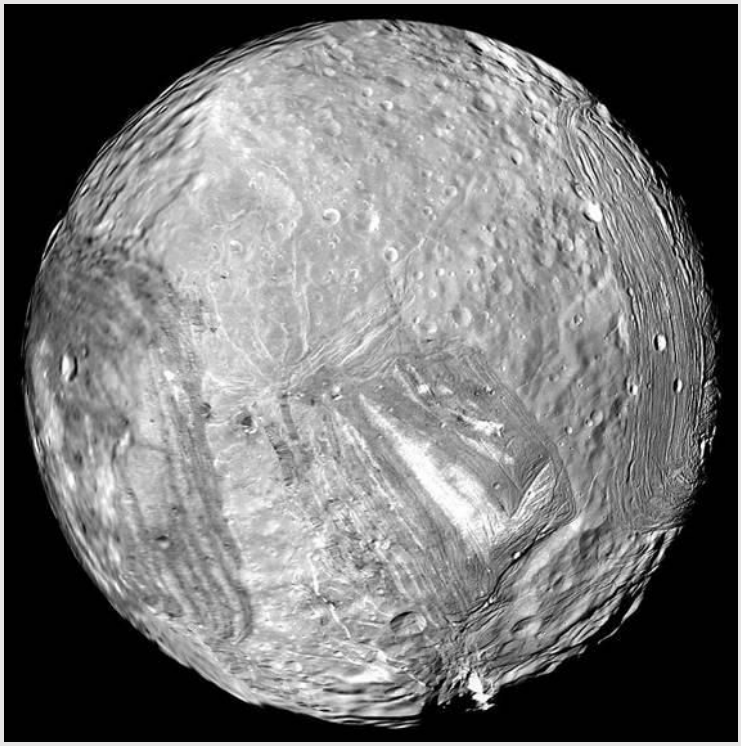
The theory is based on a separation of the concepts of the gravitational field and matter. While this may be a valid approximation for weak fields, it may presumably be quite inadequate for very high densities of matter. One may not therefore assume the **validity of the equations** for very high densities and it is just possible that in a unified theory there would be no such singularity.

**– Albert Einstein**





**Arranged in their accurate order and relative sizes**, Uranus and its six largest moons can be visualized from left to right: **Puck**, **Miranda**, **Ariel**, **Umbriel**, **Titania**, and **Oberon**.



This image of **Miranda, one of Uranus' moons,** was taken by the **Voyager 2** on **January 24, 1986.**

Every black hole loses mass until it reaches a mass of $\sqrt{\frac{\hbar c}{G}}$.

At $\sqrt{\frac{\hbar c}{G}}$ black hole disappears in a burst of radiation.

| | |
|---|---|
| 0.1 Solar mass star | lifetime ~ $2 \times 10^{12}$ years |
| Our Sun | lifetime ~ 10 billion years |
| 25 Solar mass star | lifetime ~ 7 million years |

The cosmological constant $\Lambda$ is present in cosmic space and also in our laboratory.

✓ **But its effects in the laboratory are too small to measure**

**The steady state Universe (Fred Hoyle)**

✓ **Infinitely old; Infinitely big; Constant density**

**CONTINUOUS MATTER CREATION**

Expansion creates one hydrogen atom every year in a one cubic mile volume

"The recent developments in cosmology strongly suggest that the universe may be the ultimate free lunch."

**– Alan Guth**

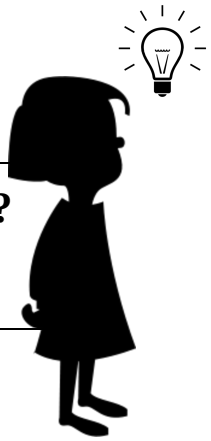
"The steady state model does not appear to agree with the observed **Luminosity distance** versus **redshift** relation or with source counts ... In a sense, this disagreement is a credit to the model; alone among all cosmologies, the steady state model makes such definite predictions that it can be disproved even with the limited observational evidence at our disposal. The steady state model is so attractive that many of its adherents still retain hope that the evidence against it will eventually disappear as observations improve. However, if the cosmic microwave radiation . . . is really black-body radiation, it will be difficult to doubt that the universe has evolved from a hotter denser early stage."

**–Steven Weinberg**

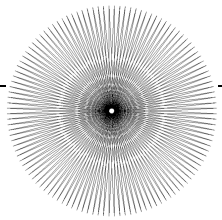
**3-dimensional quantum gravity can be represented as a "hologram" in 2 dimensions**

**Quantum field theory**

Treats gravitational waves as elementary particles – **gravitons**



## Can String Theory Describe The Quantum Space-time Foam?



**M-theory** is a theoretical framework in physics that encompasses and unifies the five different versions of string theory that were previously proposed. M-theory postulates that the basic building blocks of the universe are not strings, but rather tiny, two-dimensional membranes, or "branes". The theory proposes that our observable universe is a three-dimensional brane within a larger 11-dimensional space-time. In **M-theory**, the various forces of nature and the particles that make up matter are explained by the interactions of branes and strings in higher dimensions. The theory also suggests that there may be other parallel universes or **"hidden dimensions"** that are inaccessible to us. Like **string theory**, **M-theory** is still a developing field and has not yet been experimentally confirmed. Nevertheless, it remains an important area of research for physicists as it provides a promising framework for resolving some of the biggest mysteries of physics.

The **Planck force** is a theoretical unit of force that is considered to be the largest possible force that can exist in the universe. It is defined as the gravitational force between two bodies that are maintained apart by one Planck length and have masses of one Planck mass each. The Planck force is calculated to be approximately $1.211 \times 10^{44}$ Newton .The Planck force is considered to be the most fundamental unit of force, and it sets the scale for all other forces in the universe. In theoretical physics, the **Planck force** is used to describe the extreme conditions near black holes and other high-energy phenomena. The **Planck force** is an extremely large unit of force, and it is many orders of magnitude larger than any force that can be produced in the laboratory. As a result, it is extremely difficult to measure or detect directly. Nevertheless, it remains an important concept in physics, as it provides a fundamental limit to our understanding of the universe.



## Newton's law of universal gravitation:

$$F_G = \frac{Gm_1m_2}{r^2}$$

$$m_1 = m_2 = \sqrt{\frac{\hbar c}{G}}$$

$$r = \sqrt{\frac{\hbar G}{c^3}}$$

$$F_G = \frac{c^4}{G}$$

**Planck force** is the gravitational attractive force between two bodies of 1 Planck mass each that are held 1 Planck length apart.

## Coulomb's law:

$$F_E = \frac{q_1q_2}{4\pi\varepsilon_0 r^2}$$

$$q_1 = q_2 = \sqrt{4\pi\varepsilon_0\hbar c}$$

$$r = \sqrt{\frac{\hbar G}{c^3}}$$

$$F_E = \frac{c^4}{G}$$

**Planck force** is the electrical force between two point charges of 1 Planck charge each that are held 1 Planck length apart.

**Newton's second law:**

$$F = ma$$

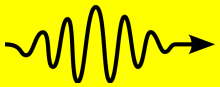
The object would accelerate twice as quickly if the force is doubled.

$$m = \sqrt{\frac{\hbar c}{G}}$$

$$a = \sqrt{\frac{c^7}{\hbar G}}$$

$$F = \frac{c^4}{G}$$

**Planck force** is the amount of force required to accelerate one Planck mass by one Planck acceleration.



## Light Behaviors

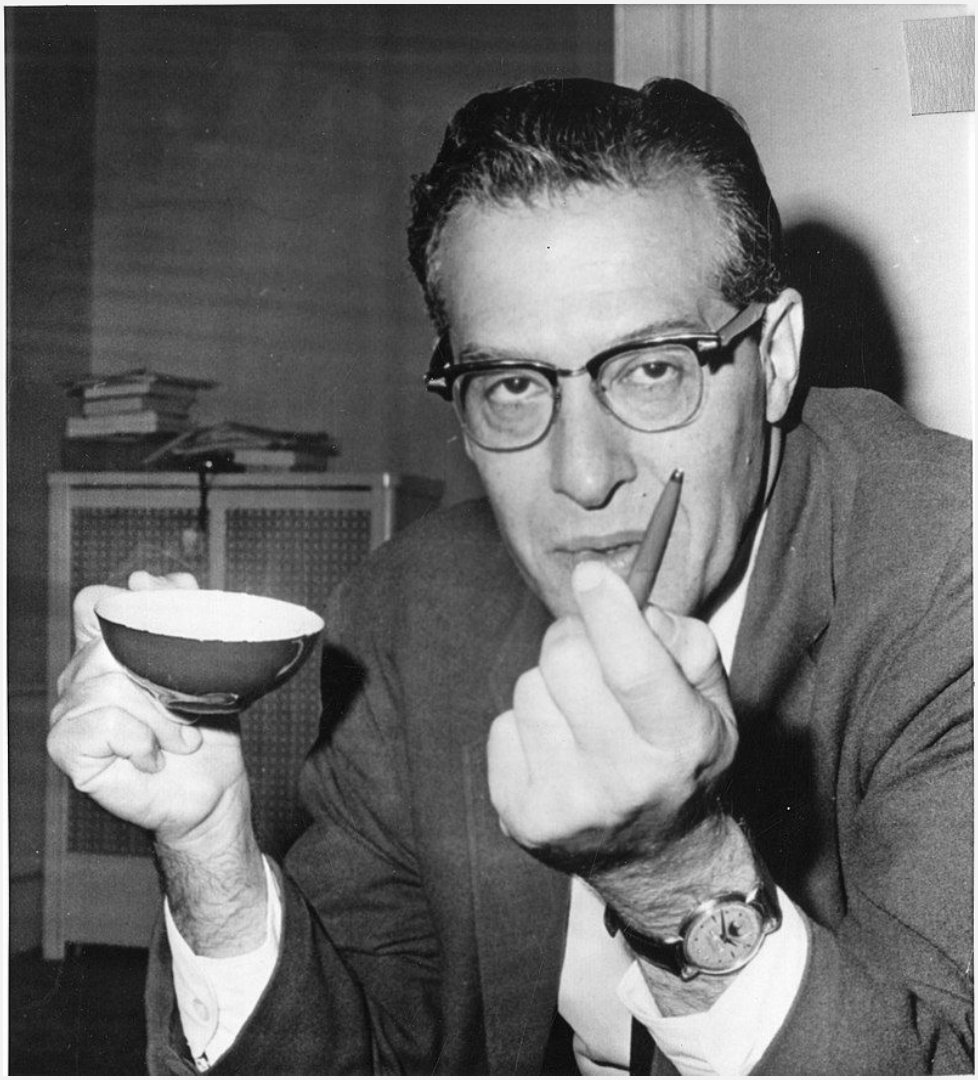
| | |
|---|---|
| **ABSORPTION** | **Light can be absorbed** |
| **EMISSION** | **Light can be emitted** |
| **TRANSMISSION** | **Light can be passed through** |
| **REFLECTION** | **Light can be bounced** |
| **REFRACTION** | **Light can be bend** |

$$PE = mgh \longrightarrow PE \propto h$$

**(Gravitational potential energy increases as height increases)**

$$KE = mv^2 / 2 \longrightarrow KE \propto mv^2$$

**(Kinetic energy changes only if mass or velocity changes)**



**Julian Schwinger** was an American physicist who was born on February 12, 1918, and passed away on July 16, 1994. He is renowned for his contributions to the advancement of **quantum electrodynamics** (QED), a model that explains interactions between charged particles and photons. **Schwinger's work** in QED earned him the **Nobel Prize in Physics in 1965**, which he shared with **Richard Feynman** and **Sin-Itiro Tomonaga**. His contributions to the field of **quantum mechanics** also include the development of the **Schwinger action principle**, which is a method for deriving the equations of motion for quantum systems. In addition to his work in physics, **Schwinger** was also known for his strong political beliefs and activism. He was a vocal opponent of the Vietnam War and spoke out against the nuclear arms race. Schwinger was a professor at Harvard University and the University of California, Los Angeles, during his career, and he trained a number of prominent physicists, including Nobel laureate **Sheldon Glashow**.

The consistency of gravity with Quantum Mechanics makes **String Theories** almost mathematically inconsistent.

**It is impossible to precisely detect the position and velocity of particles that display both particle and wave nature at the same time.**

"A well-known scientist (some say it was **Bertrand Russell**) once gave a public lecture on astronomy. He described how the earth orbits around the sun and how the sun, in turn, orbits around the center of a vast collection of stars called our galaxy. At the end of the lecture, a little old lady at the back of the room got up and said: "What you have told us is rubbish. The world is really a flat plate supported on the back of a giant tortoise." The scientist gave a superior smile before replying, "What is the tortoise standing on?" "You're very clever, young man, very clever," said the old lady. "But it turtles all the way down!"

**— Stephen Hawking**

## The work function of tungsten:

| | |
|---|---|
| **Photoelectric emission** | $7.18 \times 10^{-19}$ J |
| **Thermionic emission** | $7.23 \times 10^{-19}$ J |

$W_{\text{photoelectric emission}} < W_{\text{thermionic emission}}$

- The term "**hadrons**" is derived from the Greek **hadros** meaning large, strong.
- The term "**leptons**" is derived from the Greek **leptons** meaning light.
- The American physicist **Murray Gell-Mann** was the first to introduce the idea about the quark structure of hadrons.

The **cosmic microwave background** (CMB) constitutes 99% of all the photons in the universe and constitutes nearly 93% of the radiation energy density in the universe. This means that the energy contained within the **CMB** is almost 93% of the total energy of all forms of radiation in the universe. This makes the **CMB** the dominant form of radiation in the universe.

**Gravitational potential well:**



Photon falls in → gains energy → **Gravitational blueshift**

Photon climbs out → loses energy → **Gravitational redshift**

**Sound waves are longitudinal and mechanical.**

- $6.022 \times 10^{23}$ hydrogen atoms represent one mole of hydrogen.
- $6.022 \times 10^{23}$ water molecules represent one mole of water.

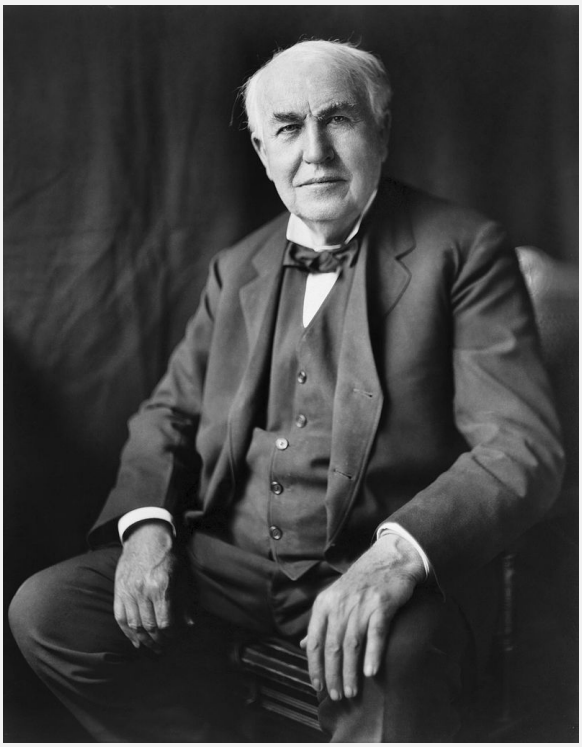
When light enters a medium with a higher index of refraction, it slows down, bends towards the normal, and has a shorter wavelength − but its frequency remains constant.

**Prior to the formation of the Rockies or the Alps, the dinosaurs went extinct.**



The Earth orbits the Sun at a speed of roughly 67,000 miles per hour (or 107,000 kilometers per hour), rotating on its axis at a speed of about 1,000 miles per hour (or roughly 1,600 kilometers per hour). The orbital speed is much faster than the rotational speed, and it is what allows the Earth to complete one orbit around the Sun every 365.25 days, giving us our annual cycle of seasons.

**Thermionic emission** is a phenomenon in which electrons are emitted from a heated surface or material. It occurs when the thermal energy of the electrons is high enough to overcome the binding energy holding the electrons in place, allowing them to escape and become free electrons. This process is also sometimes referred to as the **Edison effect**, after its discovery by **Thomas Edison** in 1883.



Thomas A Edison

**Luminosity** is the total amount of energy that the celestial object emits per unit time, while **mass** is a measure of the amount of matter contained within the celestial object. The **luminosity-mass ratio** is a measure of how much light a celestial object, such as a star, emits relative to its mass. For example, if a star has a luminosity of 10,000 $L_{Sun}$ and a mass of 2 $M_{Sun}$, then its luminosity-mass ratio would be:

$$\frac{\text{Luminosity}}{\text{Mass}} = \frac{10{,}000 \times L_{Sun}}{2 \times M_{Sun}} = 5000\,\frac{L_{Sun}}{M_{Sun}}$$

This means that the star emits 5000 times more light than the Sun for each unit of mass it contains. The **luminosity-mass ratio** is a useful parameter in astrophysics, as it gives an indication of the star's overall energy output relative to its mass.

$$\textbf{Luminosity-mass ratio} = \frac{L}{M} = \frac{\sigma T^4 \times 4\pi R^2}{M}$$

**Luminosity-mass ratio** $= \frac{L}{M} = 4\sigma T^4 \times \pi G \times \frac{R^2}{GM}$

**Luminosity-mass ratio** $\propto \frac{(\text{Absolute temperature of the star})^4}{\text{Surface gravity of the star}}$

According to **Bohr atomic model**, the negatively charged electron revolves around a positively charged nucleus in a circular orbit of radius **r**. The revolving electron in a closed path constitutes an electric current. The motion of the electron in anticlockwise direction produces conventional current $\mathbf{I = \frac{e}{T}}$ (where T is the period of revolution of the electron) in the clockwise direction.

$$\mathbf{I = \frac{ev}{2\pi r}}$$

The **orbital magnetic moment** of the electron is given by:

**$\mu$ = I × A, where A is the area of the orbit ($\pi r^2$)**

$$\mu = \frac{evr}{2}$$

$$\frac{\mu}{m_e v\, r} = \frac{e}{2m_e}$$

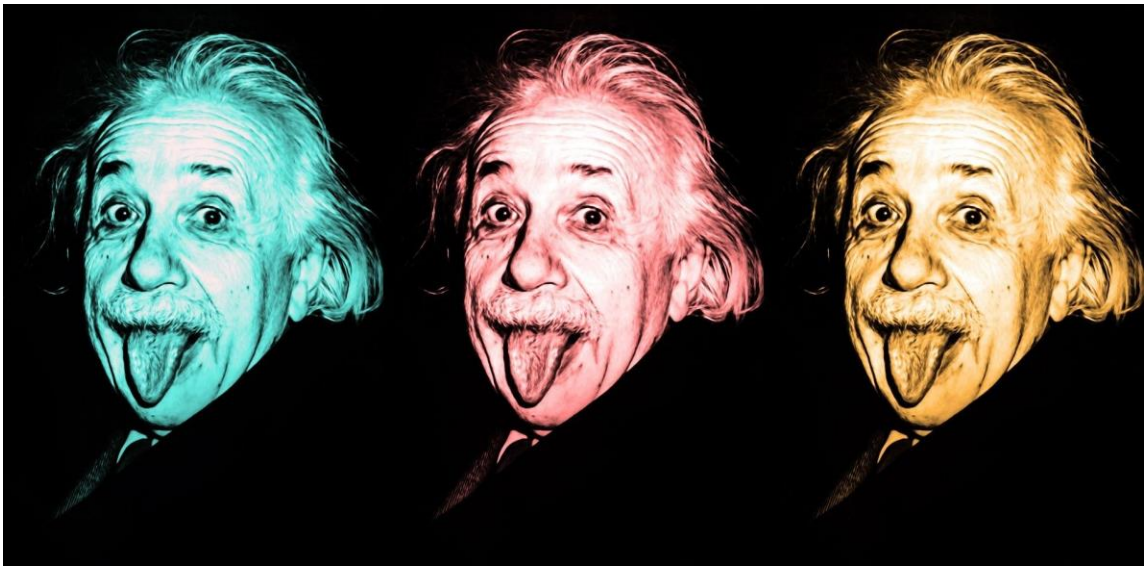
A fundamental physical constant that describes the magnetic moment of an electron in response to an applied magnetic field.

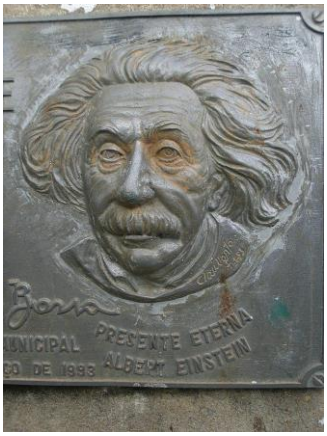
**Gyromagnetic Ratio of the Electron** $= \frac{e}{2m_e}$

**Gyromagnetic Ratio of the Electron** = $\dfrac{\text{Faraday constant}}{2 \times \text{Molar electron mass}}$

Gyromagnetic Ratio of the Electron = $\dfrac{h}{2m_e} \times \dfrac{e}{h}$

**Gyromagnetic Ratio of the Electron** = $\dfrac{\text{Quantum of circulation} \times \text{Josephson constant}}{2}$



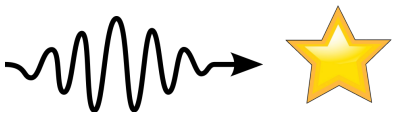


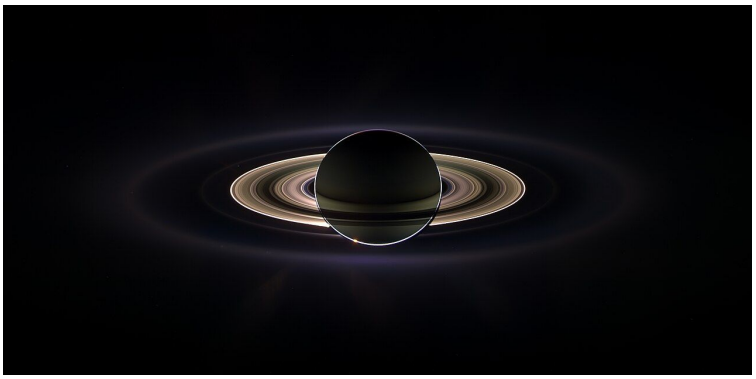



Albert Einstein

$A_2 \xrightarrow{h\upsilon} A + A$ (Photodissociation)

$A_2 \xrightarrow{heat} A + A$ (Thermal dissociation)





**Viewed from the perspective of the Cassini orbiter, an image shows Saturn passing in front of the sun, creating an eclipse-like phenomenon.**

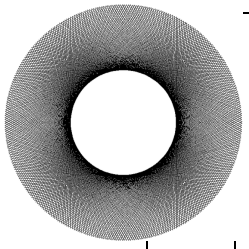
$$\text{Electron relativistic mass} = \frac{\text{Electron rest mass}}{\sqrt{1-\frac{v^2}{c^2}}}$$

✓ If Electron relativistic mass = Proton rest mass:

$$\sqrt{1-\frac{v^2}{c^2}} = \frac{\text{Electron rest mass}}{\text{Proton rest mass}} = \frac{1}{1836.1567343}$$

$$v = 0.99999985169c$$

✓ **The velocity at which an electron's relativistic mass is equal to the rest mass of a proton**



**The mean energy per photon in a blackbody radiation cavity is:**

$$E \approx \mathbf{2.7}\ k_B T$$



The total power emitted by an **accelerated electron** is given by **Larmor's formula**:

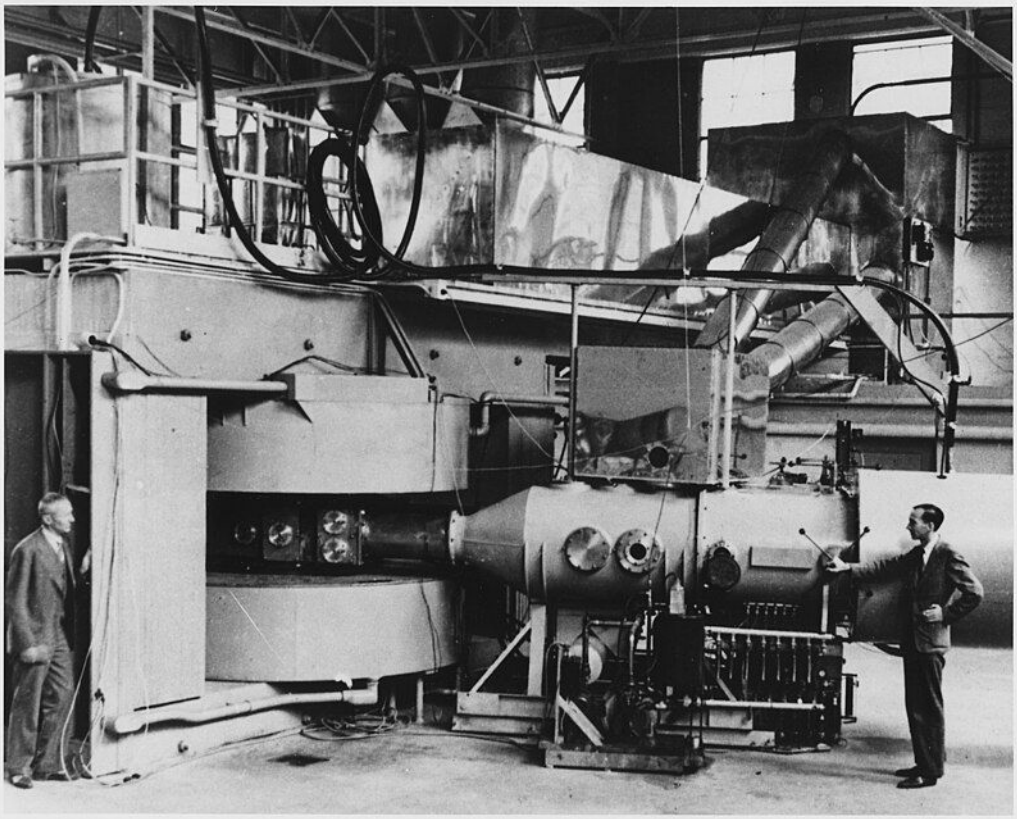
$$P = \frac{e^2 a^2}{6\pi\varepsilon_0 c^3}$$ which is valid only if $v << c$

where a is the proper acceleration, e is the electron charge, and c is the speed of light.

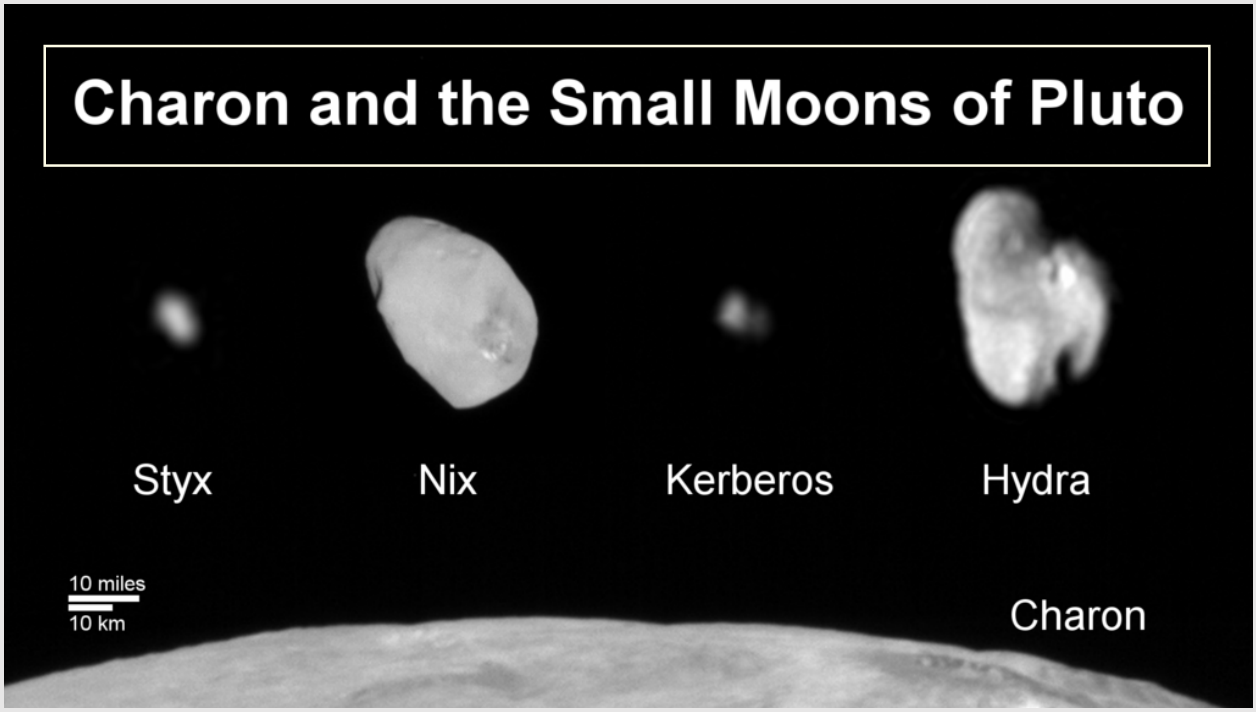
✓ **The Larmor formula highlights that the power radiated is directly proportional to the square of the acceleration of the electron.**

## ✓ False Vacuum Theory

A **scientific hypothesis** that proposes our current universe might exist within a temporary state of lower energy, within a larger overarching universe referred to as a **"false vacuum",** which could potentially decay into a lower-energy state, creating a **catastrophic event** that could disrupt the fundamental forces and particles that govern the universe, meaning that our current universe and everything we know in our visible universe is temporary and will cease to exist almost immediately without warning



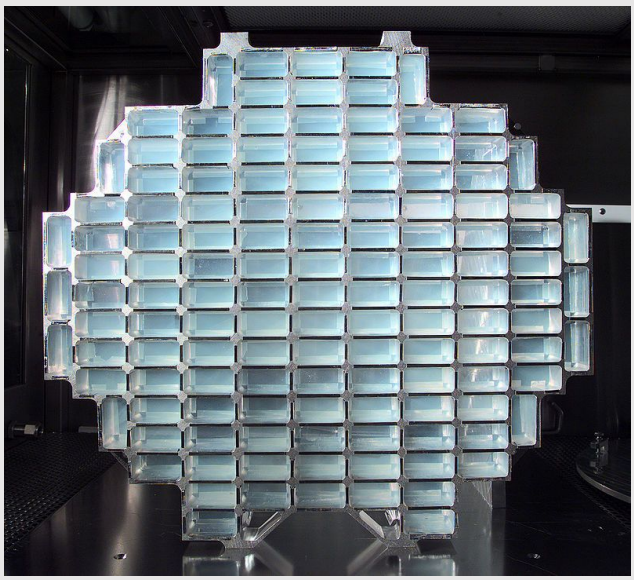
The **60-inch cyclotron** at the **Lawrence Radiation Laboratory**, University of California, Berkeley, in August 1939.




**Family Portrait of Pluto's Moons.**

## Debris disk

Also known as a **debris ring** or **dust disk**, is a flattened, rotating disk of dust, rocks, and other particles that surrounds a celestial object, such as a star or a planet.



A **dust collector** with **aerogel blocks**, as employed by missions like **Stardust** and **Tanpopo**, refers to a specialized device designed to capture and preserve dust particles or micrometeoroids from space for scientific analysis.



**Joseph Larmor** (1857–1942) was an Irish physicist and mathematician who made significant contributions to the fields of electromagnetism and theoretical physics. He is best known for his development of the **Larmor formula**, which describes the rate at which an accelerated charged particle radiates electromagnetic energy. **Larmor** also made important contributions to the study of the electron theory of metals, the theory of the gyrocompass, and the theory of relativity. He was elected as a Fellow of the **Royal Society** in 1892, and served as its president from 1924 to 1929. He was also awarded the **Copley Medal** by the Royal Society in 1933. **Larmor** spent most of his career at the University of Cambridge, where he served as a professor of natural philosophy from 1903 to 1932. He was known for his clear and concise writing style, and his lectures and textbooks were highly influential in the development of theoretical physics in the early 20th century.

**"Intelligence is the ability to adapt to change."**




**— Stephen Hawking**

The mean density of a pulsar with period **P** is:

$$\rho > \frac{3\pi}{GP^2}$$

where G is the Newtonian constant of gravitation.

The **Crab pulsar** has a period P = 0.033 s, so its **mean density** is:

$$\rho > \frac{3 \times 3.1415}{6.6743 \times 10^{-11} \mathrm{Nm^2/kg^2} \times (0.033\ \mathrm{s})^2}$$

$$\rho > 1296.6\ \mathrm{kg/m^3}$$

A **pulsar** is a highly magnetized rotating neutron star that emits beams of electromagnetic radiation out of its magnetic poles. Pulsars were first discovered in 1967 by **Jocelyn Bell Burnell** and **Anthony Hewish**, who detected regular radio pulses coming from a point in the sky that did not correspond to any known astronomical object. **Pulsars** are formed in the aftermath of a supernova explosion, when the core of a massive star collapses **under its own gravity to form a neutron star. Neutron stars** are incredibly dense, with a mass similar to that of the Sun compressed into a sphere only about 20 kilometers in diameter. They also have extremely strong magnetic fields, which can be up to a billion times stronger than the magnetic field of the Earth. As a **pulsar** rotates, it emits beams of radiation that sweep across space like the beam of a lighthouse. If the beam happens to cross the Earth, we observe a regular series of pulses at the frequency of the pulsar's rotation. **Pulsars** can emit radiation across the entire electromagnetic spectrum, including radio waves, X-rays, and gamma rays. **Pulsars** are important objects for studying the properties of extreme physics, including the behavior of matter under extreme densities and magnetic fields, as well as the emission mechanisms of **high-energy radiation**. They are also used as precision tools for testing theories of gravity and for detecting **gravitational waves**.

The rotational kinetic energy $\mathbf{E_{rot}}$ of a pulsar is related to its moment of inertia **I** by:

$$E_{rot} = \frac{2\pi^2 I}{P^2}$$

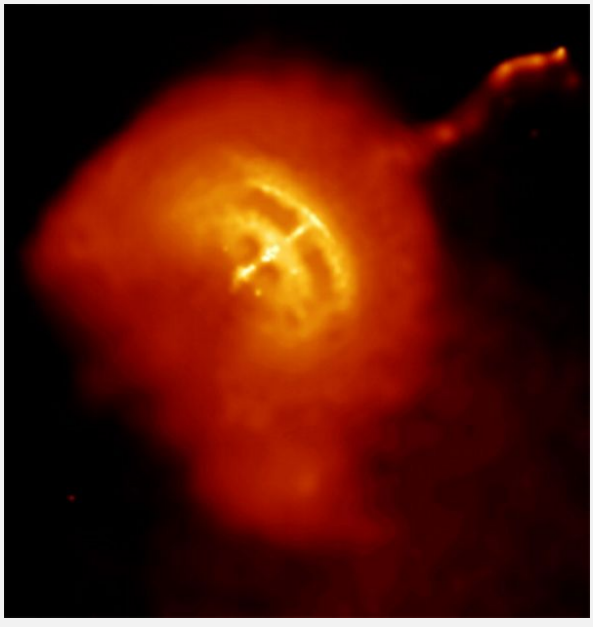
where $I = \frac{2MR^2}{5}$ (M and R denote the mass and radius of the pulsar)

**Spin-down luminosity** refers to the amount of energy that is emitted by a rotating body as it slows down due to the loss of angular momentum. This phenomenon is commonly observed in **pulsars**, which are rapidly rotating neutron stars that emit beams of electromagnetic radiation

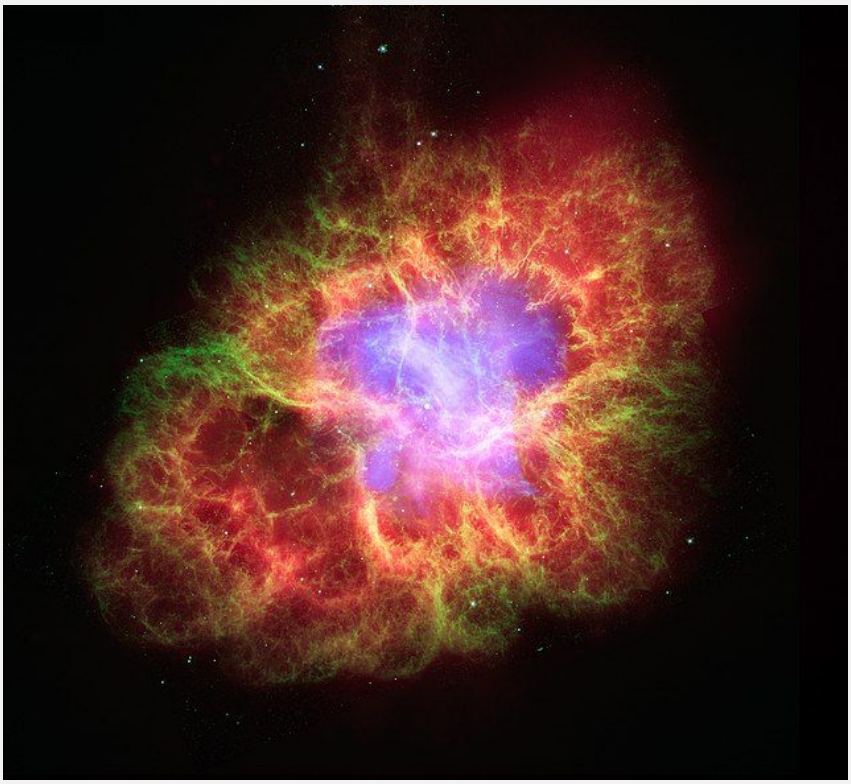
that can be detected by telescopes on Earth. As a **pulsar** loses angular momentum due to the emission of these beams, its **rotation rate** slows down and the **energy emitted per unit time**, or the **spin-down luminosity**, decreases. The **spin-down luminosity** of a pulsar can be calculated using the following equation:

$$-\frac{dE_{rot}}{dt} = \frac{4\pi^2 I}{P^3} \times \frac{dP}{dt}$$

The **spin-down luminosity** is an important quantity for studying the evolution and properties of rotating objects, such as pulsars and black holes, and for understanding the mechanisms that govern their emission of radiation.



**The Vela Pulsar and its surrounding pulsar wind nebula.**



The **Crab Nebula** is a supernova remnant located in the **constellation Taurus**, approximately 6,500 light-years away from Earth. It was first observed by Chinese astronomers in 1054 AD and was later independently discovered by Western astronomers in 1731. The **Crab Nebula** was formed as a result of a supernova explosion, which occurred when a massive star at least 8 times the mass of the Sun exhausted its nuclear fuel and collapsed under its own gravity. The explosion released an enormous amount of energy, and the resulting shockwave expelled the outer layers of the star into space, forming the nebula. The **Crab Nebula** is one of the most studied objects in astronomy, as it provides a unique opportunity to study the processes involved in the death of a massive star and the subsequent formation of a supernova remnant. The **nebula** is also a strong emitter of radiation across the electromagnetic spectrum, including radio waves, X-rays, and gamma rays, and it contains a **pulsar**, **a highly magnetized rotating neutron star**, at its center. The **Crab Nebula's pulsar** is one of the most well-known and studied pulsars, and it has provided important insights into the properties of neutron stars and the emission mechanisms of pulsars.

**Hubble parameter:**

$$H = \frac{dlna}{dt}$$

Scale factor of the universe

$$T \propto \frac{1}{a}$$

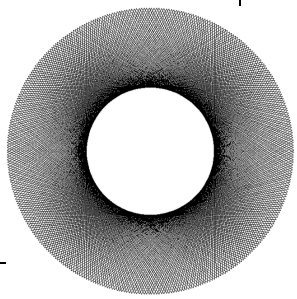
$$H \times dt = \frac{da}{a}$$

$H \rightarrow$ **constant**

$$a \propto e^{Ht}$$

$$T \propto e^{-Ht}$$

$$-\frac{dT}{dt} = HT$$



**Our Universe started to accelerate a couple of billion years ago. Before that there was a period of normal decelerated expansion, essential for the formation of galactic clusters and superclusters.**

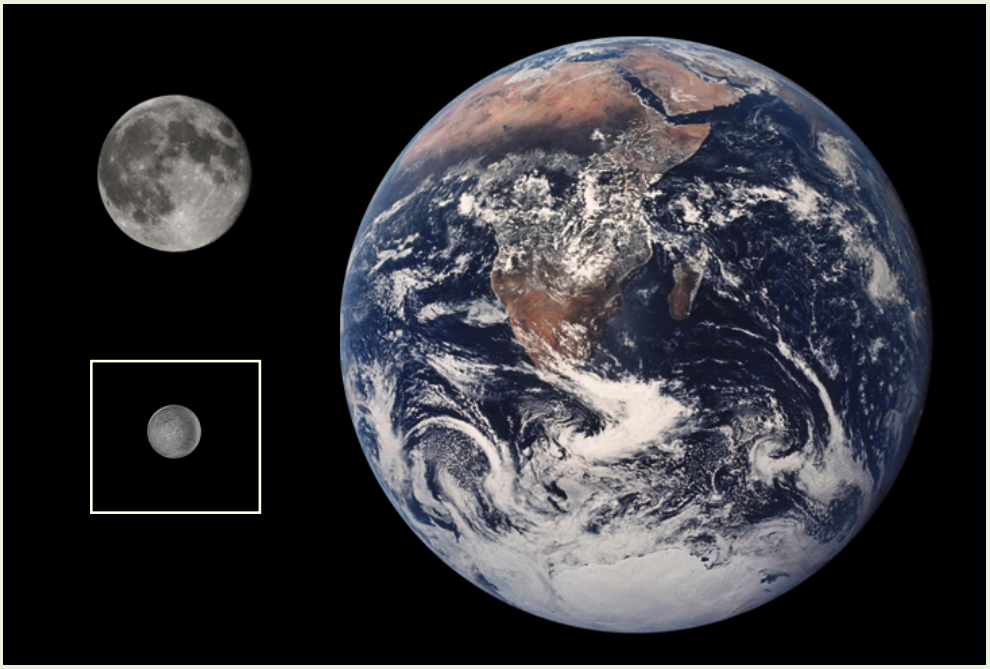
✓ **Black hole temperature:**

$$T = \frac{hc^3}{16\pi^2 GMk_B} = \frac{c_2}{8\pi^2 R_S}$$

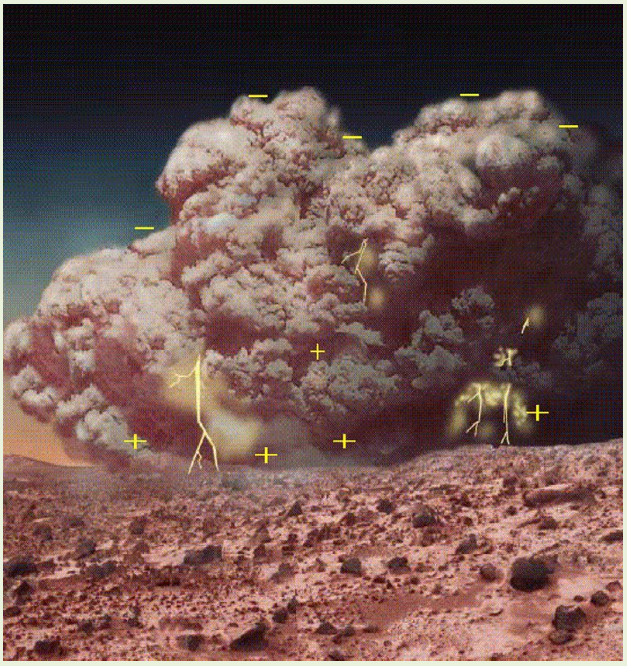
Second radiation constant

**Schwarzschild radius** of the black hole

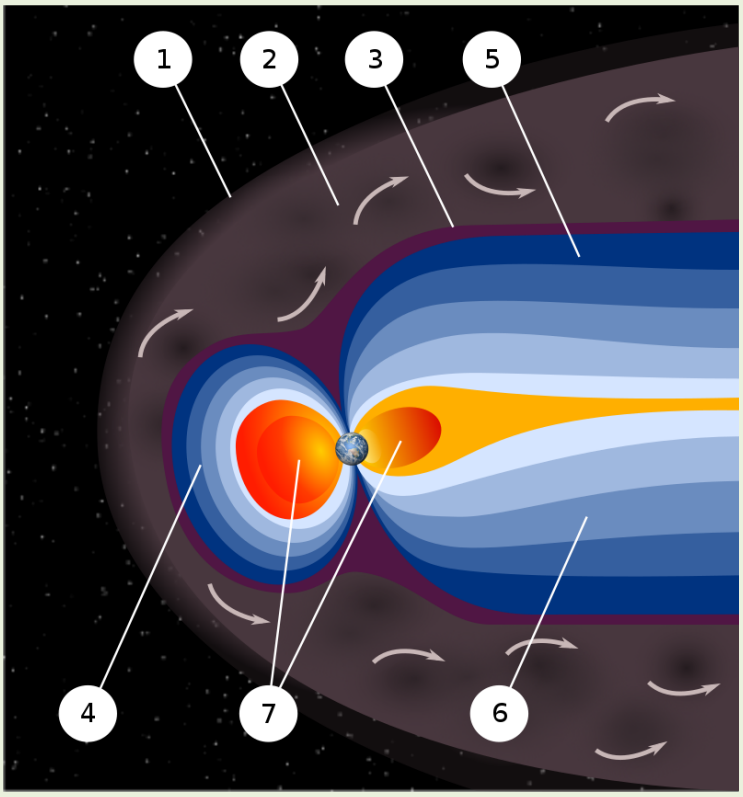
The **smaller** a **black hole** is, the hotter it will glow



Size comparison of the Uranian moon Ariel, Moon, and Earth.



**An illustration of atmospheric electricity in a Martian dust storm, which has been put forward as a potential explanation for the puzzling chemistry observed on Mars.**




**The structure of the Magnetosphere of the Earth as depicted by an artist. 1) Bow shock. 2) Magnetosheath. 3) Magnetopause. 4) Magnetosphere. 5) Northern tail lobe. 6) Southern tail lobe. 7) Plasmasphere.**

## Did you know?

The United States conducted a series of high-altitude nuclear tests known as Operation Fishbowl in 1962. One of the tests, called Starfish Prime, involved detonating a 1.4 megaton hydrogen bomb at an altitude of about 400 kilometers (250 miles) above the Pacific Ocean. The blast was about 100 times more powerful than the atomic bomb dropped on Hiroshima in 1945.

**Saturn's rings** are not solid, but are composed of billions of individual particles made up of ice, dust, and rock, ranging in size from tiny grains to larger boulders. These particles orbit **Saturn** in a flat disc-shaped region known as the ring system.





**Johann Titius** **Johann Bode**

**Known for their contributions to the development of the Titius-Bode law, also known as the Bode's law.**

Led **Johann Titius** to predict the existence of another planet between Mars and Jupiter in what we now recognize as the asteroid belt.

**Titius-Bode Law:**

The **distance** d of the $n^{th}$ **planet** from the Sun is given by:

$$d = a + 2^n b \text{ with } a = 0.4AU \text{ and } b = 0.3AU$$

The integer take values $n = -\infty$ for mercury, n = 0 for Venus, n = 1 for the Earth, and so on.

| Planet | n | Actual distance in AU | Predicted distance in AU |
|---|---|---|---|
| Mercury | $-\infty$ | 0.387 | 0.4 |
| Venus | 0 | 0.723 | 0.7 |
| Earth | 1 | 1.00 | 1.0 |
| Mars | 2 | 1.52 | 1.6 |
| Planetoids | 3 | 2.2 to 3.2 | 2.8 |
| Jupiter | 4 | 5.20 | 5.2 |
| Saturn | 5 | 9.55 | 10.0 |
| Uranus | 6 | 19.2 | 19.6 |
| Neptune | 7 | 30.1 | 38.8 |
| Pluto | 8 | 39.5 | 77.2 |

Predicted the amount of space between the planets

**Refraction**

**Waves change direction when they change medium**

When waves add up or cancel each other out: they interpenetrate each other.

**Heisenberg's Uncertainty Principle:**

$$\Delta p \times \Delta x \geq \frac{\hbar}{2}$$

$$m\Delta v \times \Delta x \geq \frac{\hbar}{2}$$

$$\Delta v \geq \frac{\hbar}{2\ m\ \Delta x}$$

Only for the exceedingly small masses of atoms and subatomic particles the product of the uncertainties becomes significant.

The position and the velocity of a subatomic particle cannot both be measured exactly, at the same time – even in theory.

$$\Delta p \times \Delta x \geq \frac{\hbar}{2}$$

$$\Delta k \times \Delta x \geq \frac{1}{2}$$

$$\Delta p = \frac{h}{\Delta \lambda} = \hbar \Delta k$$

k = angular wave number

It is impossible to specify both the position of a light signal and its wavelength with full precision

## ✓ Loschmidt's number

The number of gas molecules in one cubic centimeter at 0° C and one atmosphere pressure

$2.687 \times 10^{19}$ molecules per cubic centimeter

## ✓ Thermal energy

The energy contained within a system that is responsible for its temperature

**Heat**

The flow of thermal energy

**Joule** = Newton × meter = $\frac{\text{Kilogram} \times (\text{meter})^2}{(\text{second})^2}$

### ✓ Heliocentrism

In the center of all rests the Sun

"For those who want some proof that physicists are human, the proof is in the idiocy of all the different units which they use for measuring energy."



— **Richard P. Feynman**

The object will also move in a straight line in the absence of a net external force.

| Conservative force | Non-Conservative force |
|---|---|
| The total work done in moving a particle from one point to another is independent of the path taken by the particle. | The total work done in moving a particle from one point to another is dependent of the path taken by the particle. |
| • Gravitational<br>• Electric<br>• Elastic | • Friction<br>• Air resistance<br>• Tension in cord |

**1 horsepower = 33,000 foot pounds per minute**

**1 horsepower = 550 foot pounds per second**

| Translational | Rotational |
|---|---|
| Force = mass × acceleration | Torque = moment of inertia × angular acceleration |
| For every action there is an equal and opposite reaction. (Here action and reaction refer to forces.) | For every action there is an equal and opposite reaction. (Here action and reaction refer to torques.) |
| Power = Force × velocity | Power = Torque × angular velocity |

## ✓ Pascal's law

When an object is immersed in a fluid, it experiences equal pressure on all surfaces.

## Archimedes' principle

A body immersed in a fluid is subjected to an upward force equal to the weight of the displaced fluid

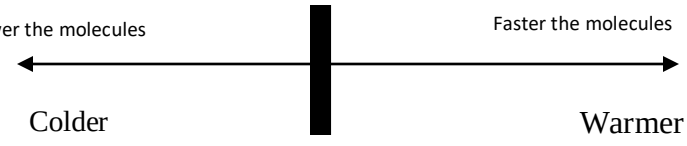
**Archimedes** was the most famous mathematician – certainly the greatest scientist of the classical age. He is most famous for discovering the law of hydrostatics − sometimes known as **'Archimedes principle'**.

Any particle smaller than an atom is called a **subatomic particle**

- Atoms of the same element are the same.
- Atoms of different elements are different.

| | |
|---|---|
| **373.15 K** | Normal boiling point of water |
| **309.9 K** | Average human body temperature |
| **273.16 K** | Triple point of water |
| **273.15 K** | Normal freezing point of water |

## Kinetic theory of gases




- The gas is composed of molecules.
- Molecules are small.
- Molecules are in constant random motion.
- Collisions between molecules are perfectly elastic.
- The temperature of a gas is a measure of the average kinetic energy of the molecules.
- All molecules have energy, but the energy varies depending on the temperature the sample of gas is in.
- The higher the speed of the molecules, the higher their temperature.



**Charles-Augustin de Coulomb**

A quantum fluctuation can create an proton antiproton pair with energy $\Delta E \geq 2m_p c^2$ provided the fluctuation lives less than the time $\Delta t \leq \frac{\hbar}{\Delta E}$. In that time, the proton and antiproton can separate by a distance of order $\Delta x = c \times \Delta t$. As they separate they gain energy $eE \times \Delta x$, in the electric field with strength E. If they gain sufficient energy to compensate for their rest mass, they no longer have to annihilate: they can become real particles. The condition for real proton− antiproton pair creation is therefore that the electric field be greater than a critical value, $E_{critical}$ given by:

$$e\,E_{critical} \times \left(c \times \frac{\hbar}{2m_p c^2}\right) = 2m_p c^2$$

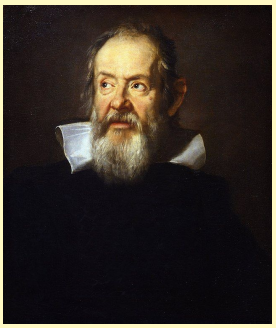
$$E_{critical} = \frac{4m_p^2 c^3}{\hbar e}$$

A modern mathematical proof is not very different from a modern machine, or a modern test setup: the simple fundamental principles are hidden and almost invisible under a mass of technical details.

— **Hermann Weyl**

## The 3 Greatest Physicists in History

In no experiment, matter exists both as a particle and as a wave simultaneously. It is either the one or the other aspect.



Galileo Galilei



Albert Einstein

**Albert Einstein** was a German-born theoretical physicist, widely acknowledged to be one of the greatest physicists of all time. Einstein is known for developing the theory of relativity, but he also made important contributions to the development of the theory of quantum mechanics.



Isaac Newton

"It was an act of desperation. For six years I had struggled with the blackbody theory. I knew the problem was fundamental and I knew the answer. I had to find a theoretical explanation at any cost, except for the inviolability of the two laws of thermodynamics."

– Max Planck

Irradiance is power per unit area.

**Just like Energy, TOTAL MOMENTUM IS ALWAYS CONSERVED**

| ✓ Classical Picture | ✓ Quantum Picture |
| --- | --- |
| Energy of EM wave ~ (Amplitude)$^2$ | Energy of photon = $\frac{hc}{\lambda}$ |




| Black hole type | Description | Constraints | |
|---|---|---|---|
| **Schwarzschild** | has no angular momentum and no electric charge | angular momentum = 0 | electric charge = 0 |
| **Kerr** | does have angular momentum but no electric charge | | electric charge = 0 |
| **Reissner–Nordström** | has no angular momentum but does have an electric charge | angular momentum = 0 | |
| **Kerr–Newman** | has both angular momentum and an electric charge | | |

The **gravitational potential of a mass distribution** of radius "R" and mass "M" is given by the expression:

$$U = -\alpha \frac{GM^2}{R}$$

where α is a constant and G is the Newtonian gravitational constant. For a constant density, $\alpha = \frac{3}{5}$

$$U = -\frac{3GM^2}{5R}$$

The **kinetic energy** is:

$$KE = \frac{Mv^2}{2}$$

Since $v^2 = 3\sigma^2$ (where σ is the velocity dispersion):

$$KE = \frac{3M\sigma^2}{2}$$

From the **virial theorem** (2KE + U = 0) it follows:

$$\sigma^2 = \frac{GM}{5R}$$

**Assuming that the mass to Luminosity ratio is constant:**

$$\frac{M}{L} = \text{constant}$$

$$M \propto L$$

Using this with the above expression, we obtain a relation between R and L :

$$R \propto \frac{LG}{\sigma^2}$$

**The surface brightness** $B = \frac{L}{4\pi R^2}$

$$L = 4\pi R^2 B$$

$$\downarrow$$

$$L \propto 4\pi R^2 B$$

$$L \propto 4\pi \left(\frac{LG}{\sigma^2}\right)^2 B$$

$$L \propto \frac{\sigma^4}{4\pi G^2 B}$$

$$\downarrow$$

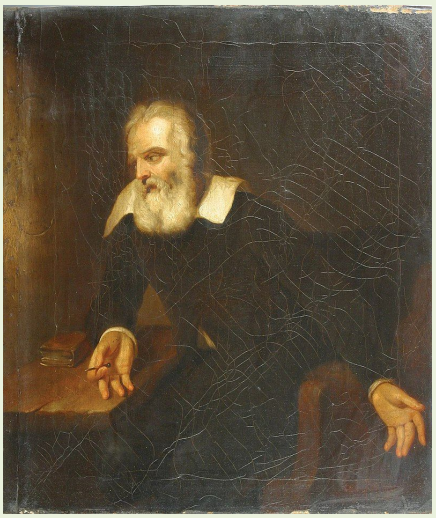
$$L \propto \sigma^4$$

**Faber-Jackson relation**

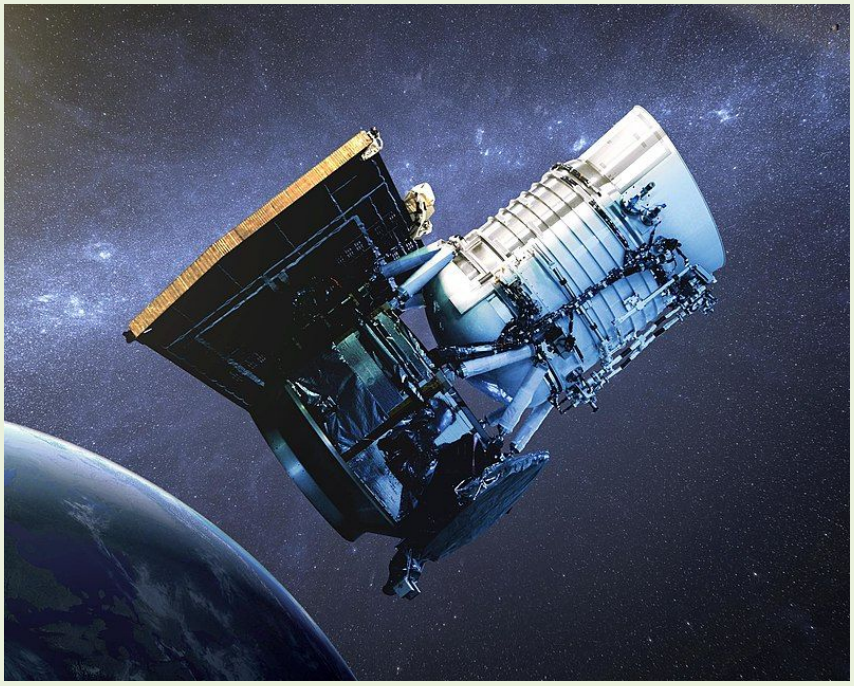
**The reduced mass of the proton-electron system is given by the equation:**

$$\mu = \frac{m_p m_e}{(m_p + m_e)} \approx 0.9995\ m_e$$

The **reduced mass** is an important quantity in **quantum mechanics**, particularly in the study of **atomic and molecular structure**, where it is used to calculate various properties such as energy levels and transition frequencies.



**Galileo is portrayed as holding a nail and looking at diagrams he has scratched on the wall of his prison cell.**



**The Wide-field Infrared Survey Explorer or WISE spacecraft is depicted orbiting the planet "Earth" in this artist's depiction.**

**The surface gravity of a Schwarzschild black hole is given by the equation:**

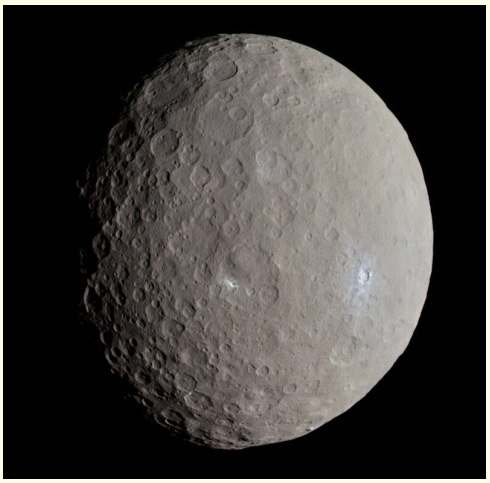
$$g = \frac{c^4}{4GM}$$

If the mass (M) of the black hole increases, the surface gravity (g) at its event horizon will decrease.

where c is the speed of light, G is the gravitational constant, and M is the mass of the black hole.

**Planck Force = 4Mg**





**Ceres**

**Giuseppe Piazzi** was an Italian astronomer and mathematician who is best known for his discovery of **Ceres**, which is now classified as a dwarf planet. **Piazzi's discovery of Ceres** on January 1, 1801, marked a significant milestone in the exploration of the solar system and played a crucial role in expanding our understanding of celestial bodies beyond the traditional planets.

# ★ Dirac large numbers hypothesis:

- The strength of gravity, as represented by the gravitational constant, is inversely proportional to the age of the universe:

$$G \propto \frac{1}{t}$$

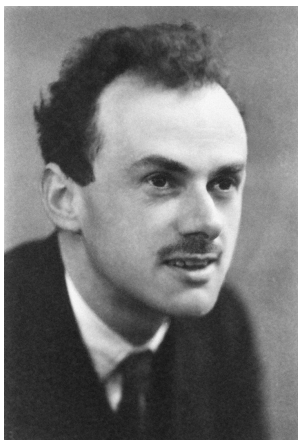
- The mass of the universe is proportional to the square of the universe's age:

$$M \propto t^2$$

- Physical constants are actually not constant. Their values depend on the age of the Universe.

# ✓ Bremermann's limit:

The maximum computational speed of a self-contained system in the material universe.



$$\frac{c^2}{h} \approx 1.36 \times 10^{50} \text{ bits per second per kilogram}$$

$$\left\{\gamma^{\mu}\left(i\frac{\partial}{\partial x^{\mu}} - eA_{\mu}\right) - m_e\right\}\Psi(x^{\nu}) = 0$$

**Dirac equation for the relativistic electron**



✓ **Gravitational strain:**



$$h = \frac{2GM}{c^2R}$$

Reveals how far we are from any possible horizon

**Strong gravity** occurs when the mass M and the distance scale R obey:

$$\frac{2GM}{c^2R} \approx 1$$

Gravity is strong near black holes, near the horizon of the universe and at extremely high particle energies.

Science is the acceptance of what works and the rejection of what does not. That needs more courage than we might think.

**– Jacob Bronowski**

**Black night sky** imply that our cosmos once was extremely small and then expanded rapidly

| | |
|---|---|
| **Novae** | Luminosity < $10^{31}$ W |
| **Supernovae** | Luminosity < $10^{36}$ W |
| **Hypernovae** | Luminosity < $10^{37}$ W |

A black hole is independent of how it has formed and of the materials used when forming it

| | |
|---|---|
| **Supermassive black holes** | $10^5$ to $10^{11}$ solar mass |
| **Intermediate black holes** | 50 to $10^5$ solar mass |
| **Stellar black holes** | 1 to 50 solar mass |
| **Primordial black holes** | Below 1 solar mass |
| **Micro black holes** | Below 1 gram |

The **Mesoscopic scale** is the length at which quantum mechanical behaviors in liquids or solid can be described by macroscopic concepts.

- In nature there is no rest.
- There is motion inside any substance that has mass and takes up space by having volume.
- In nature there is no perfectly straight or perfectly uniform motion.

$$r_e = \frac{e^2}{4\pi\varepsilon_0 m_e c^2}$$ { 10,000 times smaller than an atom and is roughly the length scale at which renormalization becomes significant in quantum electrodynamics }

**Any length scale containing e is a quantum length scale and not a classical length scale – because e is the quantum of electric charge.**



**Interference** between 2 different photons never occurs.

Faster-than-light motion is possible in the **quantum world**

→ { **Tachyonic particle** }

**The quantum mechanics implies:**

- There is no **state of remaining unchanged indefinitely** in nature
- The vacuum is not empty
- Matter particles behave like waves

**Quanton**

↓

Any **quantum entity** that shows the properties of both a particle and a wave

The transition from the classical case to the quantum case → quantization

**White light** is polychromatic since it is made up of multiple wavelengths − whereas red, orange, yellow, green, blue and violet lights are **monochromatic**.

→ Single frequency

**Helium** was discovered in 1868 by an English scientist and astronomer **Sir Joseph Norman Lockyer** in the spectrum of a solar eclipse.

Polarized light has electric fields oscillating in one direction − whereas Unpolarized light has electric fields oscillating in all directions

✓ **The law of reflection**

↓

When a ray of light reflects off a surface, the angle of incidence is equal to the angle of reflection.

A current of **one ampere** is the transfer of approximately $6.2415 \times 10^{18}$ elementary charges per second.

**Geomagnetism** is the study of the magnetic field of the Earth.

$$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$$

- When $q_1$ and $q_2$ have the same sign **their product is positive** − which means the force is repulsive.
- When $q_1$ and $q_2$ have the opposite sign **their product is negative** − which means the force is attractive.

$$F = m \times \frac{dv}{dt}$$

**Cause of change = resistance to change × rate of change**

**An inertial reference frame is one that is not accelerating.**

**Einsteinian Special theory of relativity**

↓

The demolition of the concept of absolute time and absolute distance

## Gibbs Paradox

In the case of 2 different ideal gases, mixing is accompanied by an entropy increase $\Delta S = 2R\ln 2 = 11.53$ J/K.

In the case of same ideal gases there is no entropy change: $\Delta S = 0$.

where R is the ideal gas constant

### ✓ Exchange symmetry

The property of nature that observations are unchanged under exchange of identical particles

**2 fermions cannot occupy the same quantum state.**



Particles that follows Fermi–Dirac statistics and generally possess half odd integer spin

In (3 + 1) **space-time dimensions**, only fermions and bosons exist.

**Quantum information**

The information of the state of a quantum system

### ✓ No-communication theorem

Instantaneous sharing of information between two observers is an impossibility

$$F_G = \frac{GMm}{r^2}$$

Sterile neutrinos are hypothetical heavier cousins of ordinary neutrinos and would interact with other matter only through the force of gravity – making them essentially impossible to detect.

especially useful when we plan to put a satellite in orbit or chart the course of the moon

Mathematics reveals its secrets only to those who approach it with pure love, for its own beauty.

**– Archimedes**

**Ginsberg's theorem**

**(Laws of Thermodynamics in terms of a person playing a game)**

- There is a game (consequence of **Zeroth law of thermodynamics**)
- You can't win (consequence of **first law of thermodynamics**)
- You can't break even (consequence of **second law of thermodynamics**)
- You can't quit the game (consequence of **third law of thermodynamics**)

**A law predicts what happens and a theory explains why**



**In 1913:** Franck and Hertz independently proved the quantum nature of atomic energy levels.

The day science begins to study non-physical phenomena, it will make more progress in one decade than in all the previous centuries of its existence.



**– Nikola Tesla**

**The controversial Anthropic Principle**

The universe can only exist such that **carbon-based life** can arise

✓ **Unified field theory**

Quantum physics + Albert Einstein's theory of general relativity

✓ **Bohr Correspondence principle**



The nuclear forces account for the attractive force between:

- a proton and a neutron
- 2 protons
- 2 neutrons

For large orbits and for large energies, quantum calculations must agree with classical calculations.

**Semi-classical physics** → a theory in which one part of a system is described quantum mechanically whereas the other is treated classically.

| Condition | |
|---|---|
| Einstein's special theory of relativity → classical mechanics | velocities are very small compared to the speed of light |
| Einstein's General theory of relativity → Newtonian gravity | weak gravitational fields |
| Statistical mechanics → thermodynamics | the number of particles is large |
| Laplace's theory of celestial mechanics →Kepler's theory of celestial mechanics | interplanetary interactions are ignored |

**Electrons can exist in states of positive energy as well as negative energy states:**

$$E = \pm\sqrt{m_0^2c^4 + p^2c^2}$$

- The positive root permits the total energy "E" of an electron to have any value from $m_0c^2$ to $+\infty$
- The negative root permits the total energy "E" of an electron to have any value from $-\infty$ to $-m_0c^2$

As momentum increases

The formation of a non-radioactive element from a radioactive element constitute

| Disintegration Series | Parent Element | Last Stable element |
|---|---|---|
| Thorium Series | $_{90}Th^{232}$ | $_{82}Pb^{208}$ |
| Neptunium Series | $_{93}Np^{237}$ | $_{83}Bi^{209}$ |
| Uranium Series | $_{92}U^{238}$ | $_{82}Pb^{206}$ |
| Actinium Series | $_{92}U^{235}$ | $_{82}Pb^{207}$ |

The naturally occurring radioactive elements conform to 4 radioactive series

The notable consequences of the Heisenberg's **uncertainty principle:**

- The path of a particle is not defined in **quantum physics** (the study of matter and energy at the most fundamental level).
- Electrons do not exist inside the nucleus of the atom.
- **Atomic oscillators** possess a certain amount of energy, known as the zero-point energy, even at absolute zero temperature.

## ✓ Length Contraction:

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

For v = 0.9c:

$L = 0.44L_0$.

That is the measured length is less than half of the proper length. If v << c, then L and $L_0$ are nearly equal. At low velocities, relativity approaches classical mechanics — our everyday experiences have negligible relativistic effects.



**An inertial frame is a frame of reference in which Newtonian first law holds well.**

**The Galilean principle of relativity:**

If two cars are moving at the same speed in the same direction, then a passenger in either car will not be able to notice that either car is moving.

- The **special theory of relativity** deals with observations made in inertial frames.
- The **general theory of relativity** deals with observations made in non-inertial frames.

## ✓ The relativity of simultaneity

**The negative outcome of the Michelson–Morley experiment (1887)**

↓

**The aether did not exist**

2 events are defined to be simultaneous if an observer measures them as occurring at the same time. They are not necessarily simultaneous to all observers — **simultaneity** is not absolute.

**Color of stars and total energy they emit depends on their temperatures**

$$v = \frac{da}{dt} = Ha$$

**Rate of expansion of the universe**

**Scale factor of the universe** (which is a dimensionless quantity that describes how the size of the universe changes over time)

**Inflation** $\longrightarrow \frac{dv}{dt} > 0$

**Luminous baryonic matter** – which includes stars, planets and gas – makes up less than one percent of the total density of the universe.

✓ **A very rapid expansion of the Universe**

$$\rho c^2 + 3p < 0$$

$$\rho < -\frac{\rho c^2}{3}$$

- $p \rightarrow$ pressure
- $\rho \rightarrow$ density

✓ If the universe is empty with no matter or radiation present, then the **density of the universe** would be:

The **cosmological constant** is a fundamental constant of nature, meaning that it has the same value throughout the universe and cannot be changed. The **cosmological constant** is a very small number, with a value of around $10^{-52}$ $m^{-2}$. This extremely small value has led some physicists to propose that the **cosmological constant** might be a result of quantum fluctuations in the vacuum of space. The **cosmological constant** has important implications for the ultimate fate of the universe. If the value of the **cosmological constant is positive**, the expansion of the universe would be accelerating − indicating that galaxies would be moving away from each other at an increasing rate. If the value of the **cosmological constant is negative**, the expansion of the universe would be decelerating − indicating that the mutual gravitational attraction of galaxies would be slowing down the expansion of the universe. If the value of the **cosmological constant is zero**, it would mean that the expansion of the universe is determined solely by the density of matter and energy contained within it. In this case: if the density is high enough, the gravitational attraction of matter and energy would eventually slow down the expansion of the universe and cause it to collapse back in on itself, leading to a **Big Crunch scenario**. If the density is too low, the universe would continue to expand forever, but at a constant rate, eventually becoming dark and cold as all matter and energy becomes more and more diffuse.

$$\rho = \frac{\Lambda c^2}{8\pi G}$$

Cosmological constant

Density parameter of the universe

$$\rho = \Omega \times \rho_{critical}$$

Critical density of the universe

$$\frac{\Lambda c^2}{8\pi G} = \Omega \times \frac{3H^2}{8\pi G}$$

$$\Omega = \frac{\Lambda c^2}{3H^2}$$

**Although $\Lambda$ is a constant, $\Omega$ is not since $H$ varies with time.**

Footprints left on the Moon won't disappear as there is no wind.

**Free neutrons decay into protons with a half-life of 614 seconds**

Pluto is smaller than the United States.

Any free-moving liquid in outer space will form itself into a sphere.

**Only 5% of the universe is visible from Earth.**

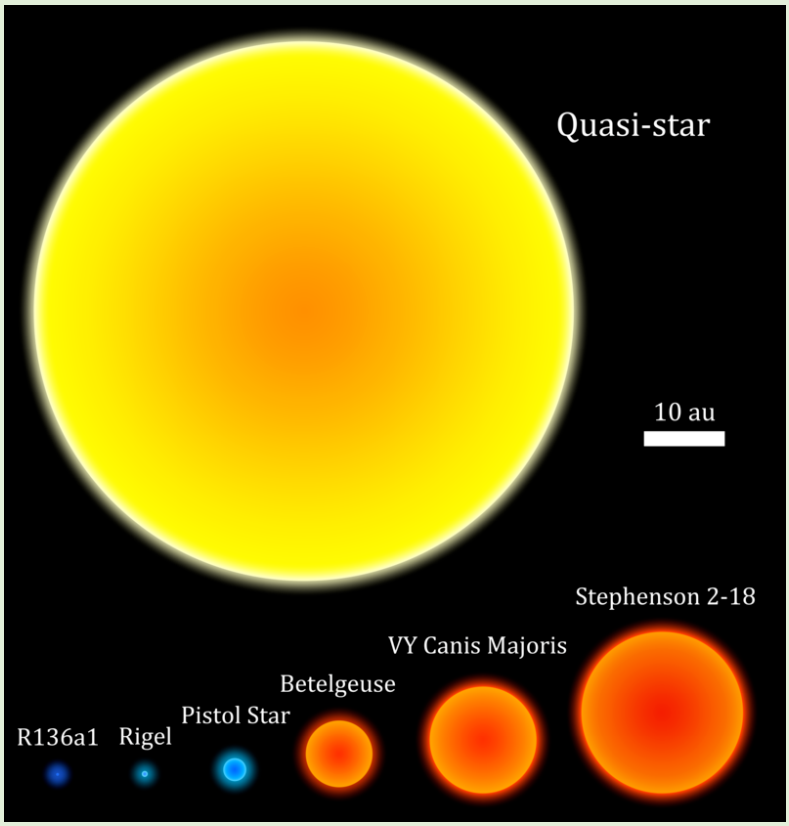
Light travels from the Sun to the Earth in less than 10 minutes.

**On Venus, it snows metal and rains sulfuric acid.**

**Using the naked eye, you can see 3 – 7 different galaxies from Earth.**

## Q-PACE

This **orbital spacecraft mission**, referred to as **Cu-PACE** (CubeSat Particle Aggregation and Collision Experiment), aimed to investigate the initial phases of proto-planetary accretion.




**Size comparison of a hypothetical quasi-star to some of the largest known stars.**

## Coatlicue

A hypothetical star that is believed to have played a role in the formation of our Sun before undergoing a **supernova explosion**.

A year on Mercury takes 88 Earth days.

A year on Venus takes 225 Earth days.

**There are more stars in space than there are grains of sand in the world.**

**There are 79 known moons orbiting Jupiter.**

**We could fit about 985 Jupiters inside of the Sun.**

**There are more volcanoes on Venus than any other planet in our solar system.**

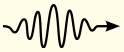
✓ **Composition of Venus atmosphere:**

- Carbon dioxide: 96 %
- Nitrogen: 3.5 %

**+**

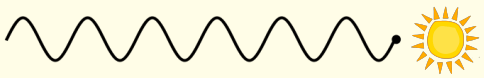
Trace amounts of carbon monoxide, argon, sulfur dioxide and water vapor (≈ 0.5%)

**Pluto is one third water**





**Venus rotates in the opposite direction to most other planets.**



**Venus is the second brightest object in the night sky.**



**Neptune's moon (Triton) orbits the planet backwards**



## Composition of Mercury atmosphere:

- 42% oxygen
- 29% sodium
- 22% hydrogen
- 6% helium
- 0.5% potassium

+

Trace amounts of argon, carbon dioxide, water, nitrogen, xenon, krypton and neon

**Pluto's largest moon – Charon–is half the size of Pluto.**

**It's not known who discovered Mercury**

## Composition of Saturn atmosphere:

**Neptune's equatorial clouds take 18 hours to make one rotation.**

- 96.3% hydrogen
- 3.25% helium
- 0.45% methane

**Pluto is smaller than Earth's moon.**



**Saturn orbits the Sun once every 29.4 Earth years.**

**A day on Uranus lasts 17 hours and 14 minutes.**

**Pluto was reclassified from a planet to a dwarf planet in 2006.**

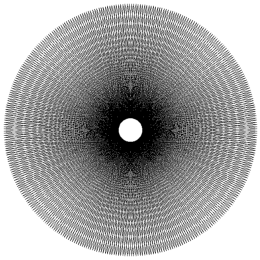
| | |
|---|---|
| $\rho c^2 + 3p < 0$ | Universe accelerates |
| $\rho c^2 + 3p > 0$ | Universe decelerates |

**p → pressure**

**ρ → density**

**Saturn has 150 moons and smaller moons, but only 13 of which have diameters larger than 50km.**

- **Mercury** is named after the Roman god of travel.
- **Venus** is named after the Roman goddess of love and beauty.
- **Mars** is named after the Roman god of War.
- **Jupiter** is named after the king of the Roman gods.
- **Saturn** is named after the Roman god of agriculture.
- **Uranus** is named after the ancient Greek king of the gods.
- **Neptune** is named after the Roman god of the Sea.
- **Pluto** is named after the Roman god of the underworld.



**Earth is the only planet not named after a God.**

**Earth, Mercury, Venus and Mars (**inner planets**)**

Made of rock – containing common minerals like feldspars and metals like magnesium and aluminum

**Jupiter, Saturn, Neptune and Uranus (**gas giants**)**

Made up mostly of trapped helium, hydrogen and water

The **uncertainty principle of quantum mechanics** prevents any speculation in times < $\sqrt{\frac{\hbar G}{c^5}}$ after the Big Bang.

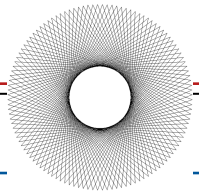
**The 4 fundamental forces of nature** — gravity, electromagnetic, weak and strong interactions — **are thought to be unified at** $\sqrt{\frac{\hbar G}{c^5}}$

**Neptune has 14 moons all of which are named after minor water gods from Greek mythology.**

## Photon

**The faster it is vibrating, the more energy it carries.**

- **rapid vibration** corresponds to a higher frequency and a shorter wavelength
- **slow vibration** corresponds to a lower frequency and a longer wavelength



**For massive stars:**

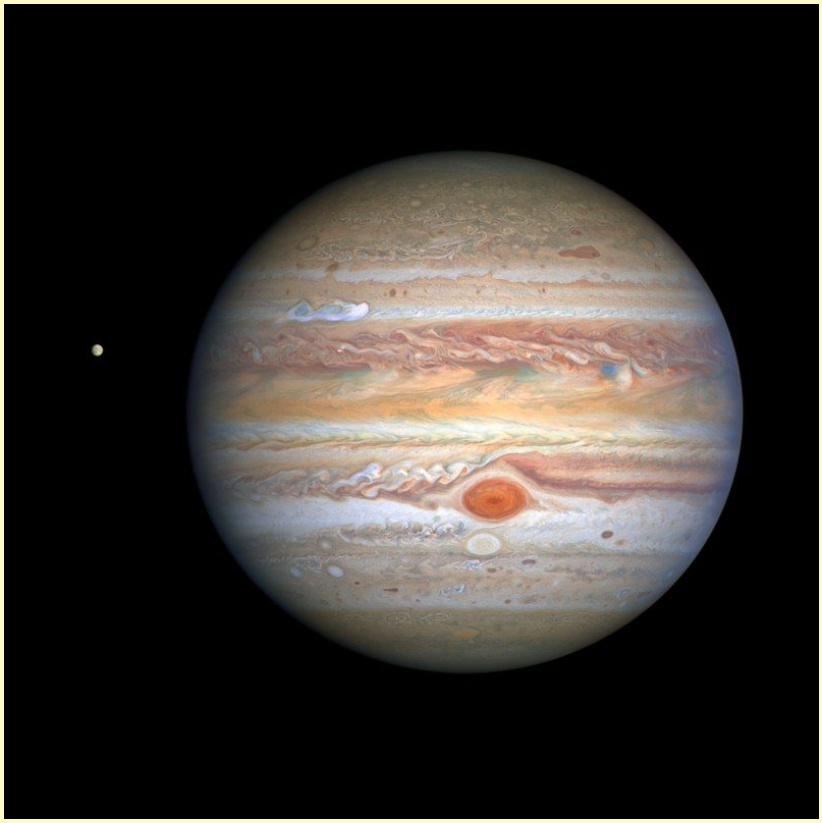
$$\textbf{Luminosity} \propto (\textbf{Mass})^4$$

$$\textbf{Lifetime} = \frac{\text{Amount of fuel}}{\text{Rate of fuel consumption}} \propto \frac{\text{Mass}}{\text{Luminosity}} \propto \frac{\text{Mass}}{(\text{Mass})^4} \propto (\text{Mass})^{-3}$$

**For less massive stars:**

$$\textbf{Luminosity} \propto (\textbf{Mass})^3$$

$$\textbf{Lifetime} = \frac{\text{Amount of fuel}}{\text{Rate of fuel consumption}} \propto \frac{\text{Mass}}{\text{Luminosity}} \propto \frac{\text{Mass}}{(\text{Mass})^3} \propto (\text{Mass})^{-2}$$



**Jupiter with its moon Europa on the left.**

**Earth's diameter is 11 times smaller than Jupiter, and 4 times larger than Europa.**

## ✓ Composition of Mars atmosphere:

- Carbon dioxide: 95.32%
- Nitrogen: 2.7%
- Argon: 1.6%
- Oxygen: 0.13%
- Carbon monoxide: 0.08%

**Mars and Earth have approximately the same landmass**

+

**Minor amounts** of water, nitrogen oxide, neon, hydrogen-deuterium-oxygen, krypton and xenon.

**Brahmanda Purana**

Golden womb, the Hiranyagarbha or Brahmanda, the **Cosmic Egg**

The golden fetus or embryo that floating in a dark void – contracted and gave birth to the universe

## Atomist Universe

**All of reality and all the objects in the universe are made up of a combination of very small, indivisible and indestructible building blocks known as atoms and an infinite void (which is empty space).**

**Aristotelian cosmology**

The earth is the center of the universe, and all the planets, stars, sun and all heavenly bodies revolve around the earth

## Copernican Universe

The sun is at the centre of the solar system, with the planets (including the earth) orbiting it.

**After the Big Bang explosion, the Universe experienced a period of exponential inflation. Then it slowed down, and the energy converted into matter and radiation.**

## ✓ Archimedes' Principle

- If the weight of the water displaced is less than the weight of the object, the object will sink
- If the weight of the water displaced is equal to the weight of the object, the object will float

Astronomy was not studied by Kepler, Galileo, or Newton for the practical applications which might result from it, but to enlarge the bounds of knowledge, to furnish new objects of thought and contemplation in regard to the universe of which we form a part; yet how remarkable the influence which this science, apparently so far removed from the sphere of our material interests, has exerted on the destinies of the world!



**— Joseph Henry**

**The first black hole wasn't discovered until X-ray astronomy was used.**



**The Galilean moons: Io, Europa, Ganymede, and Callisto listed from left to right in order of increasing distance from Jupiter.**

**Bacteria represent the world's greatest success story. They are today and have always been the modal organisms on earth; they cannot be nuked to oblivion and will outlive us all. This time is their time, not the 'age of mammals ' as our textbooks chauvinistically proclaim. But their price for such success is permanent relegation to a microworld, and they cannot know the joy and pain of consciousness. We live in a universe of trade-offs; complexity and persistence do not work well as partners.**

— **Stephen Jay Gould**

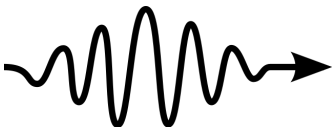
**Autoionization**

An excited atom subsequently decays resulting in the ejection of one of the outer-shell electrons, thus going from a state with charge Z to a state with charge Z + 1

✓ **Black holes distort space-time and slow time.**

There's a supermassive black hole at the heart of the Milky Way — it's four million times more massive than the sun.

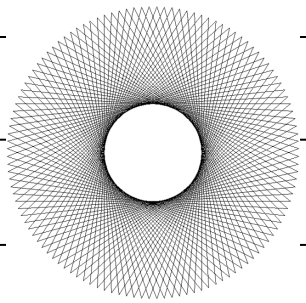
**New stars are called protostars. These are formed in nebulae nurseries.**



## ✓ Bohr Atomic Model

Failed to account for the helium spectrum or the chemical bonds of molecules

**Negatively charged electrons** are found only in specific fixed circular paths or orbits around the **positively charged nucleus**. Electrons move around the nucleus at certain energy levels represented as n =1, n=2, n=3, etc.



Our sun is so hot it produces enough energy every second equal to 100 billion hydrogen bombs

**By the 18th century science had been so successful in laying bare the laws of nature that many thought there was nothing left to discover. Immutable laws prescribed the motion of every particle in the universe, exactly and forever: the task of the scientist was to elucidate the implications of those laws for any particular phenomenon of interest. Chaos gave way to a clockwork world. But the world moved on …Today even our clocks are not made of clockwork. … With the advent of quantum mechanics, the clockwork world has become a lottery. Fundamental events, such as the decay of a radioactive atom, are held to be determined by chance, not law.**

— Ian Stewart

**Rayleigh scattering**

The scattering of light in which the frequency of the scattered light is not changed

**Light is a type of electromagnetic radiation and different colors corresponds to different wavelengths of light.**

| Color | Wavelength |
|---|---|
| red | 630 nm |
| orange | 610 nm |
| yellow | 580 nm |
| green | 532 nm |
| blue | 480 nm |

**Exothermic reaction**

The mass of the incident system is larger than that of the final system

Photographic magnitude is the apparent magnitude of a star as recorded on a photographic plate.

**Cosmology** is a science which has only a few observable facts to work with. The discovery of the cosmic microwave background radiation added one—the present radiation temperature of the universe. This, however, was a significant increase in our knowledge since it requires a cosmology with a source for the radiation at an early epoch and is a new probe of that epoch. More sensitive measurements of the background radiation in the future will allow us to discover additional facts about the universe.

**— Robert Woodrow Wilson**

**Induced fission of $^{235}U$ by thermal neutrons**

Thermal neutron + $^{235}U \rightarrow {}^{236}U \rightarrow A + B$

**Isoelectronic**

**Atoms that have the same number of electrons**

A spectrograph is an instrument used to obtain and record an astronomical spectrum.

Each nerve cell receives connections from other nerve cells at six sites called synapses. But here is an astonishing fact—there are about one million billion connections in the cortical sheet. If you were to count them, one connection (or synapse) per second, you would finish counting some thirty-two million years after you began. Another way of getting a feeling for the numbers of connections in this extraordinary structure is to consider that a large match-head's worth of your brain contains about a billion connections. Notice that I only mention counting connections. If we consider how connections might be variously combined, the number would be hyperastronomical—on the order of ten followed by millions of zeros. (There are about ten followed by eighty zero's worth of positively charged particles in the whole known universe!)

**— Gerald Maurice Edelman**

- Planck mass = $2.17647 \times 10^{-8}$ kg
- Planck length = $1.6229 \times 10^{-33}$ cm
- Planck time = $5.39116 \times 10^{-44}$ s

**Planck scale** at which the quantum effects of gravity become important.

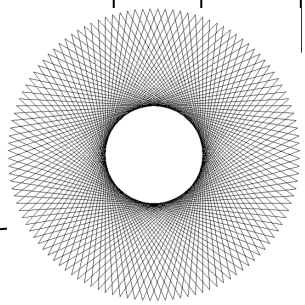
**Quantum gravitation** → The study of quantum fields in a curved space representing space-time

| | |
|---|---|
| **α-decay** | The heavy nucleus decays by emitting an helium nucleus |
| **β-decay** | The heavy nucleus decays by emitting an electron and neutrino |
| **γ -decay** | The heavy nucleus decays by emitting a gamma ray photon |

| | |
|---|---|
| **lanthanides** | elements having atomic numbers 58 to 71 |
| **actinides** | elements having atomic numbers 90 to 103 |

**Even if there is only one possible unified theory, it is just a set of rules and equations. What is it that breathes fire into the equations and makes a universe for them to describe? The usual approach of science of constructing a mathematical model cannot answer the questions of why there should be a universe for the model to describe. Why does the universe go to all the bother of existing?**

**— Stephen W. Hawking**



**Shadow matter**

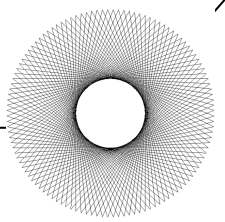
Unseen matter in the universe and is visible only through gravitational interaction in the modern theory of superstrings

**Uncontrolled fusion reaction**

Hydrogen bomb

**Stochastic electrodynamics**

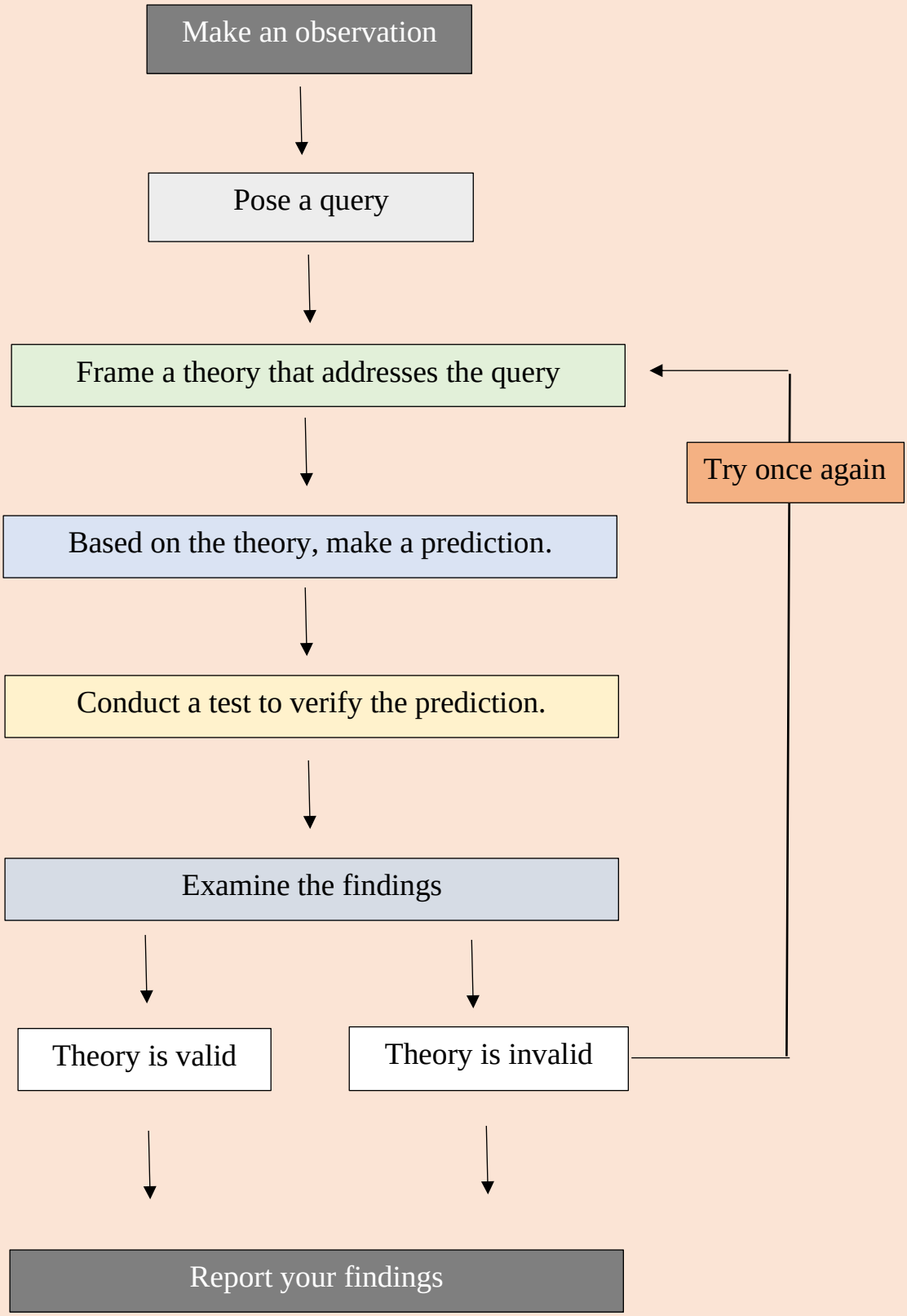
Theory of electrodynamics that tries to replace quantum fluctuations with stochastic processes



Every new theory as it arises believes in the flush of youth that it has the long sought goal; it sees no limits to its applicability, and believes that at last it is the fortunate theory to achieve the 'right' answer. This was true of electron theory—perhaps some readers will remember a book called **The Electrical Theory of the Universe by de Tunzelman**. It is true of general relativity theory with its belief that we can formulate a mathematical scheme that will extrapolate to all past and future time and the unfathomed depths of space. It has been true of wave mechanics, with its first enthusiastic claim a brief ten years ago that no problem had successfully resisted its attack provided the attack was properly made, and now the disillusionment of age when confronted by the problems of the proton and the neutron. When will we learn that logic, mathematics, physical theory, are all only inventions for formulating in compact and manageable form what we already know, like all inventions do not achieve complete success in accomplishing what they were designed to do, much less complete success in fields beyond the scope of the original design, and that our only justification for hoping to penetrate at all into the unknown with these inventions is our past experience that sometimes we have been fortunate enough to be able to push on a short distance by acquired momentum.

**— Percy W. Bridgman**

**Superheavy elements** are the chemical elements with atomic numbers greater than 103.




**Hypothesis-based science:**

A fundamental approach in the scientific method that entails formulating a testable hypothesis that attempts to explain a particular phenomenon or make predictions about a particular set of observations.

## Paleontology:

A branch of science that focuses on finding, identifying, and interpreting fossilized remains of extinct plants, animals, and other species.

## Descriptive science:

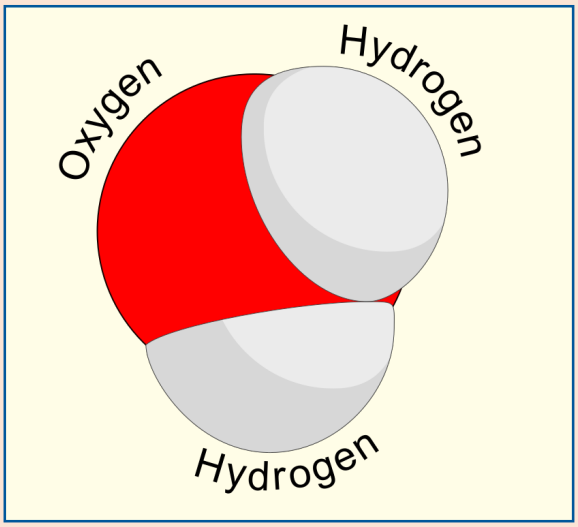
A branch of science that involves the observation, documentation, description, and classification of phenomena.

## Deductive Reasoning:

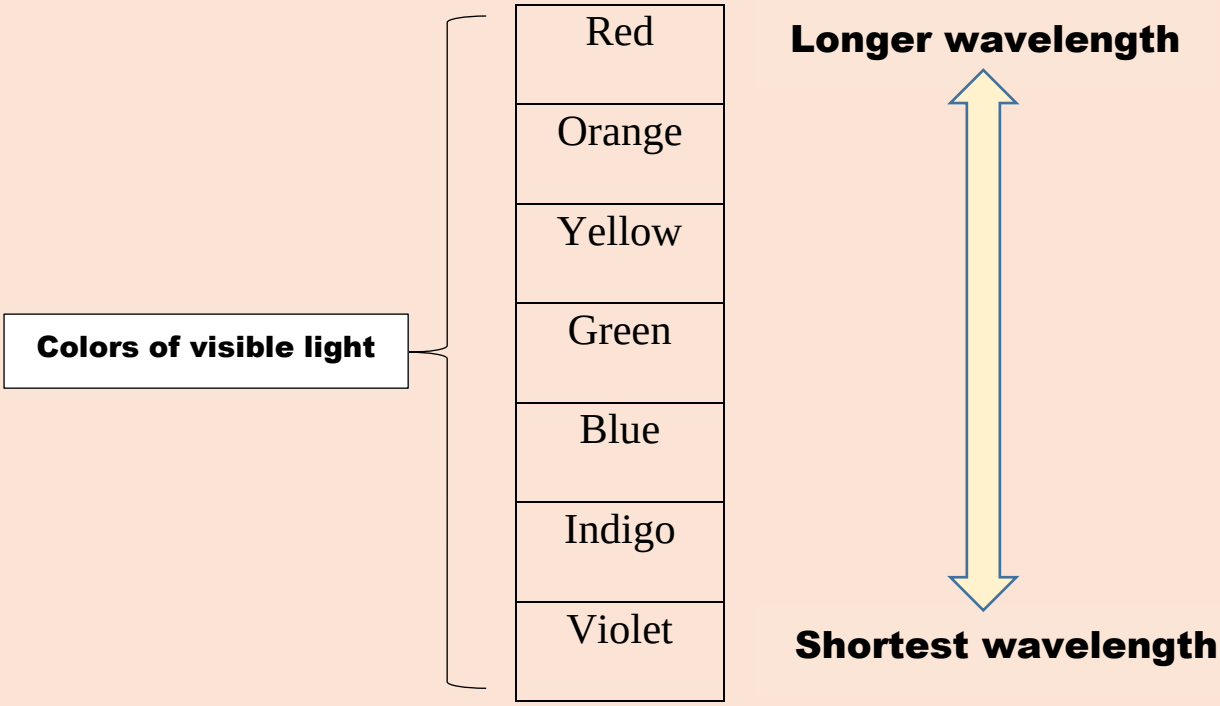
**Idea → Observation**

## Inductive Reasoning:

**Observation → Idea**

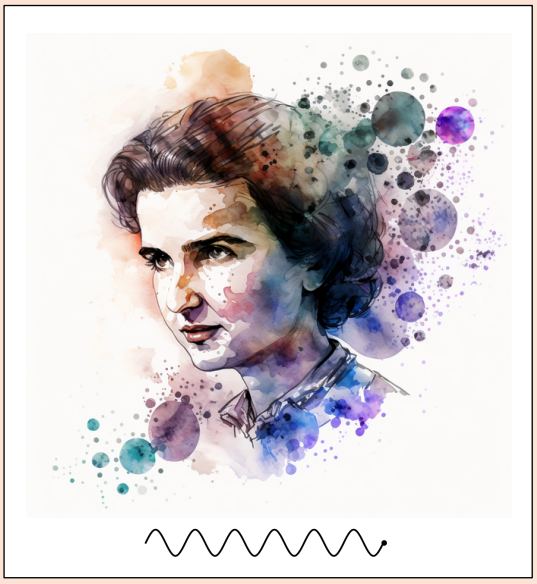



**When 2 hydrogen atoms and an oxygen atom share electrons via covalent bonds, a water molecule is formed.**

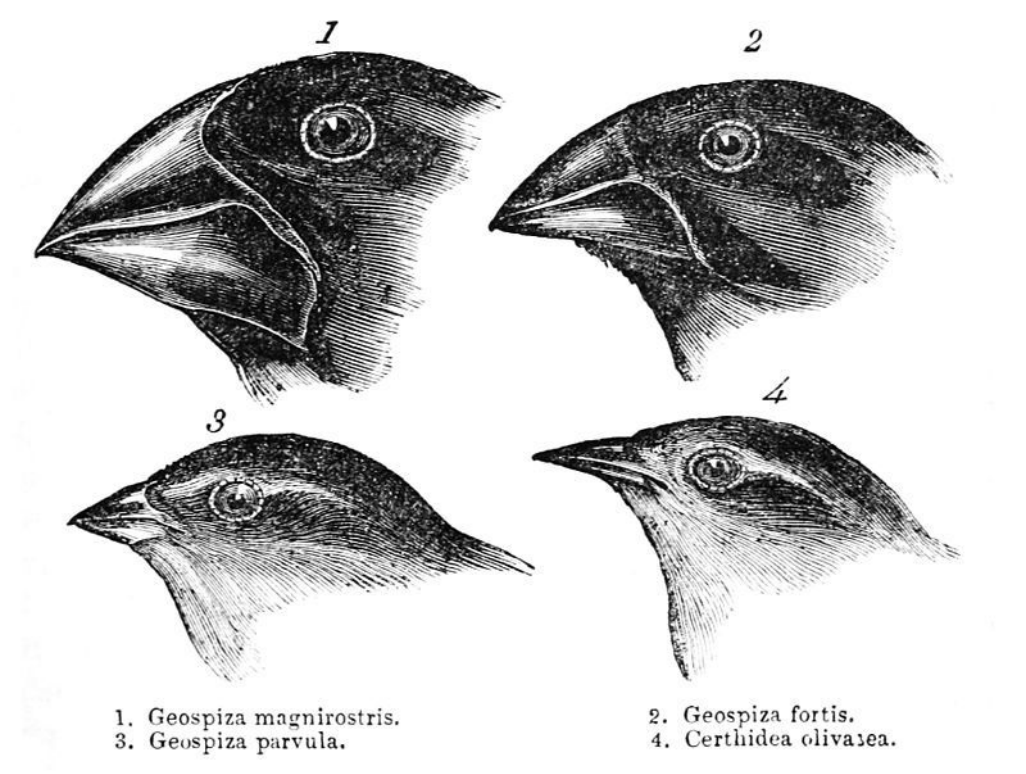



The energy carried by the various colors of visible light differs. Red has the longest wavelength and a smallest amount of energy, while violet has the shortest wavelength and consequently carries the largest amount of energy.

| ✓ Product Rule | ✓ Sum Rule |
|---|---|
| For independent events A and B, the probability (P) of them both occurring (A and B) is ($P_A \times P_B$) | For mutually exclusive events A and B, the probability (P) that at least one occurs (A or B) is ($P_A + P_B$) |



Dr. Rosalind Franklin's X-ray diffraction work made it possible to discover the structure of DNA in 1953. Her work demonstrated the double-helix structure of deoxyribonucleic acid, the molecule that contains the genetic blueprints for the development of every living organism.




During his visit to the Galápagos Islands in the 1830s, **Charles Darwin** noted that the finches on different islands had distinct variations in their beak shapes. **Darwin** hypothesized that these variations in beak shape were the result of **natural selection** acting on ancestral finch populations. According to his **theory of evolution by natural selection**, individuals within a population exhibit variation, and those with traits that provide them with a survival advantage are more likely to survive and reproduce. Over time, this leads to the accumulation of beneficial traits in a population. **In the case of the finches**, Darwin proposed that an ancestral finch species had colonized the **Galápagos Islands**. As the finches spread to different islands with varying ecological conditions and food sources, they faced different selective pressures. Those individuals with beak shapes that were better suited for obtaining specific types of food had a higher chance of survival and reproductive success. **For example,** finches with large, strong beaks were better equipped to crack hard seeds, while finches with slender beaks were more adept at probing flowers for nectar. Over generations, **natural selection** favoured individuals with beak shapes that were advantageous for exploiting the available food sources on each island. **Darwin's observations** of the finches and his postulation of adaptive radiation, where a single ancestral species gives rise to multiple species adapted to different ecological niches, played a significant role in the development of his theory of evolution. The **finches of the Galápagos Islands** became one of the iconic examples of **natural selection** and provided compelling evidence for the diversity of life through the mechanism of adaptation to specific environments.

## Eukaryote-first hypothesis

(eukaryotic cells evolved before prokaryotic cells)

## Prokaryote-first hypothesis

(prokaryotic cells evolved before eukaryotic cells)

| | |
|---|---|
| **Acidophiles** | Organisms that thrive in **highly acidic** environments, typically with a **pH** 3 or below |
| **Alkaliphiles** | Organisms that thrive in alkaline environments, typically with a **pH** 9 or above |
| **Thermophiles** | Organisms that thrive in **high-temperature** environments, typically between 41 and 122 °C |
| **Hyperthermophiles** | Organisms that thrive in **extremely high-temperature** environments, typically above 80°C and often exceeding 100°C. |
| **Psychrophiles** | Organisms that thrive in **low-temperature** environments, ranging from −20 °C to 20 °C. |
| **Halophiles** | Organisms that thrive in environments with **high salt concentrations** |
| **Osmophiles** | Organisms that thrive in environments with **high osmotic pressure** |





**ASTROPHYSICS**: Apply the laws of physics in space

**ASTROMETRY**: Map the celestial bodies

**ASTROGEOLOGY**: Examine the rocks, geographic area and material in space

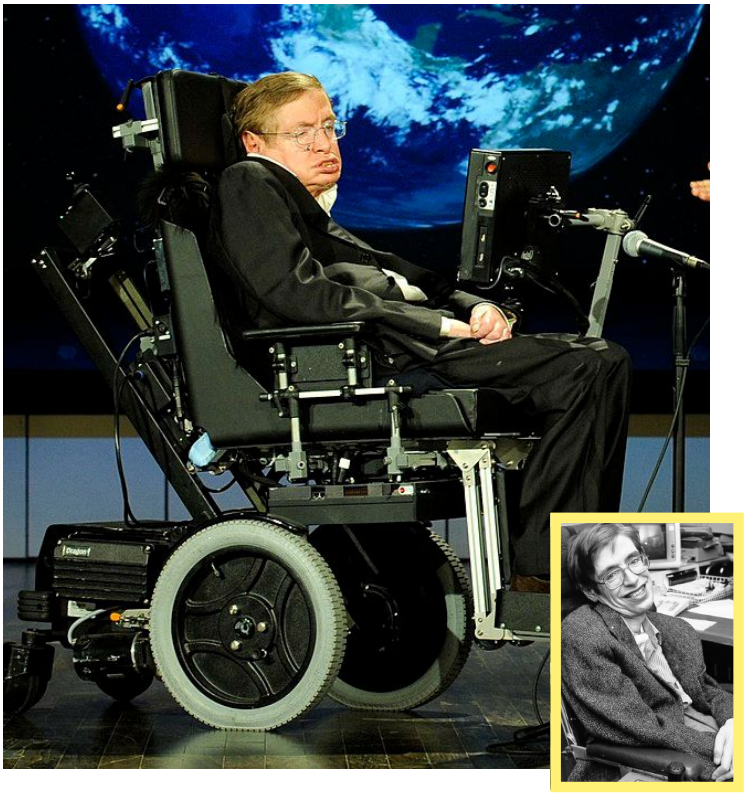
**ASTROBIOLOGY**: Search for life outside Earth



| Planet | **Minimum surface temperature (°C)** | **Maximum surface temperature (°C)** |
|---|---|---|
| **Mercury** | − 170°C | + 449°C |
| **Venus** | + 465°C | + 465°C |
| **Earth** | − 89°C | + 58°C |
| **Moon** | − 173°C | + 127°C |
| **Mars** | −125°C | + 20°C |

Human evolution is nothing else but the natural continuation, at a collective level, of the perennial and cumulative process of "psychogenetic" arrangement of matter which we call life. … The whole history of mankind has been nothing else (and henceforth it will never be anything else) but an explosive outburst of ever-growing cerebration. … Life, if fully understood, is not a freak in the universe — nor man a freak in life. On the contrary, life physically culminates in man, just as energy physically culminates in life.

**— Pierre Teilhard de Chardin**



**I believe alien life is quite common in the universe, although intelligent life is less so. Some say it has yet to appear on planet Earth.**

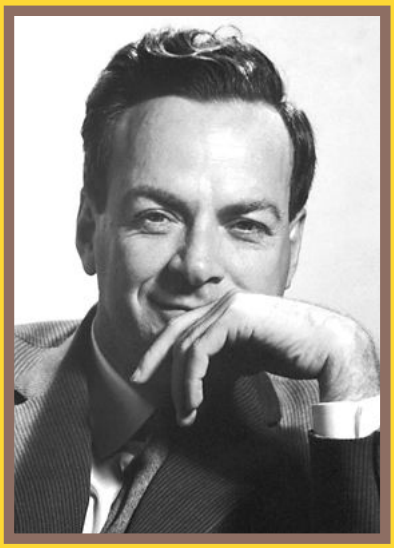
— S. Hawking

**COSMOLOGY**

How our physical universe was originated, evolved from the Big Bang to today and on into the future.

If the rate of expansion one second after the Big Bang had been smaller by even one part in a hundred thousand million million, it would have recollapsed before it reached its present size. On the other hand, if it had been greater by a part in a million, the universe would have expanded too rapidly for stars and planets to form.

The most obvious characteristic of science is its application: the fact that, as a consequence of science, one has a power to do things. And the effect this power has had need hardly be mentioned. The whole industrial revolution would almost have been impossible without the development of science.



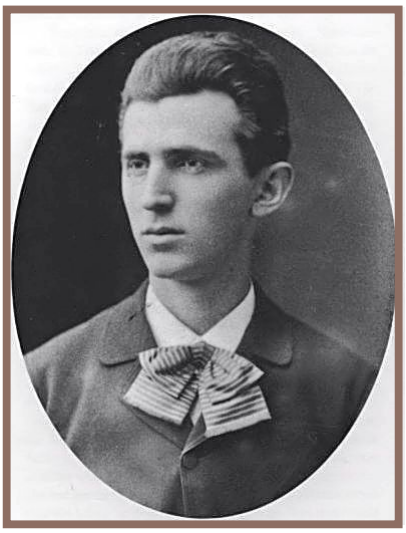
Richard P. Feynman

**We are at the very beginning of time for the human race. It is not unreasonable that we grapple with problems. But there are tens of thousands of years in the future. Our responsibility is to do what we can, learn what we can, improve the solutions, and pass them on.**

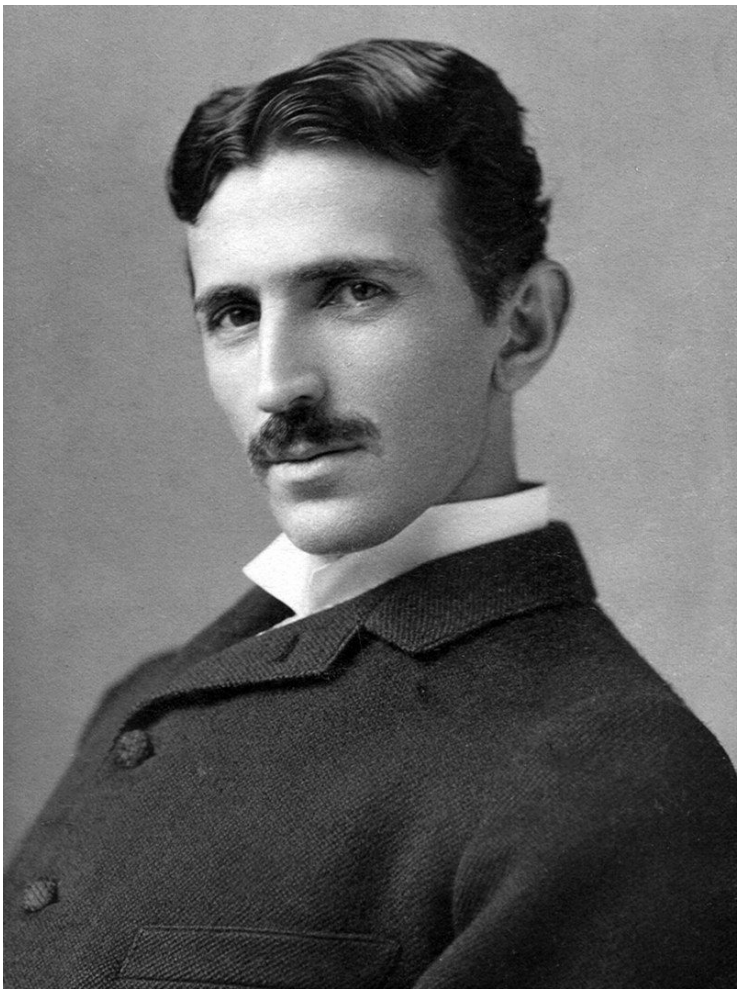


**SPECTROSCOPY**

Interaction between matter and electromagnetic radiation as a function of the wavelength or frequency of the radiation



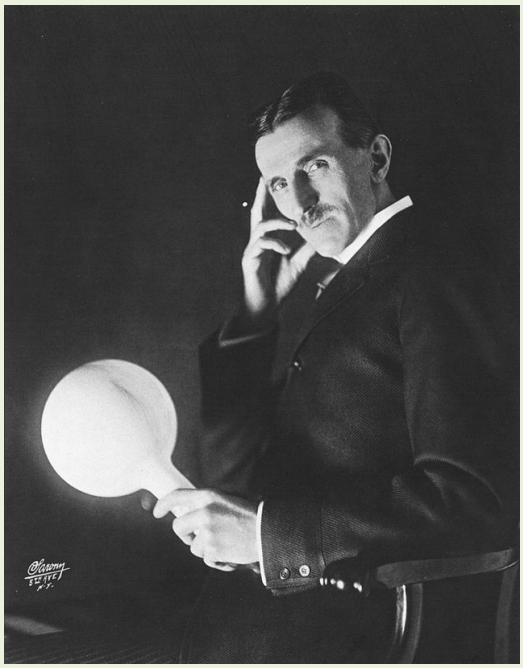
**Tesla aged 23, c. 1879**



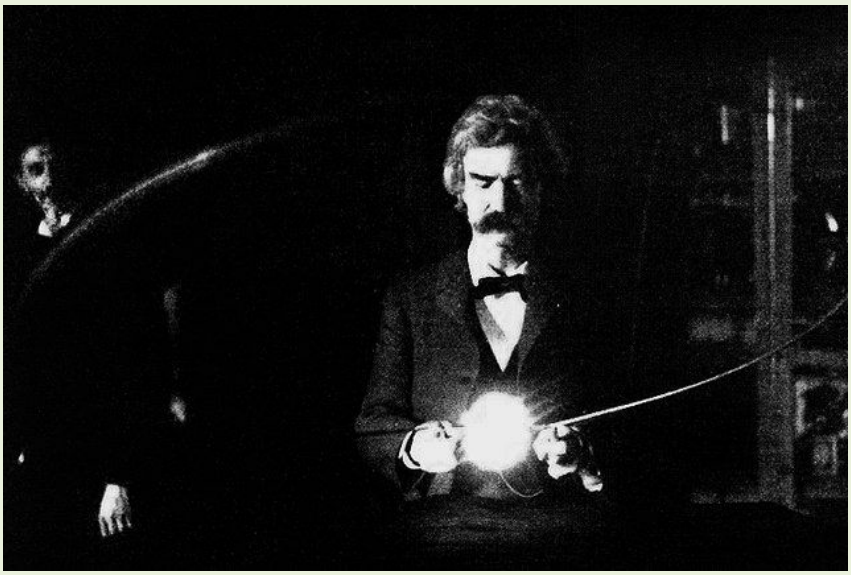
Nikola Tesla

**Modern science says:** 'The sun is the past, the earth is the present, the moon is the future.' From an incandescent mass we have originated, and into a frozen mass we shall turn. Merciless is the law of nature, and rapidly and irresistibly we are drawn to our doom.

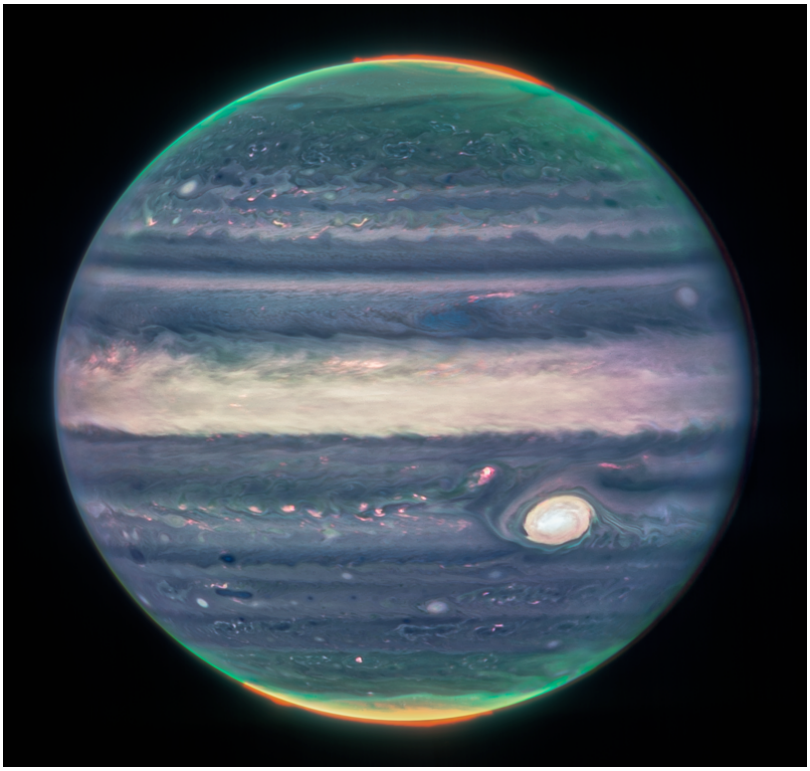
**Nikola Tesla** was a renowned inventor and engineer who made significant contributions to the fields of electrical engineering and physics during the late 19th and early 20th centuries. However, despite his many achievements, **Tesla** was also the victim of several betrayals and setbacks during his career. One of the most significant betrayals Tesla experienced was at the hands of his former employer, Thomas Edison. In the early 1880s, Tesla began working for **Edison** at his **Menlo Park laboratory** in New Jersey. **Tesla's first task** was to improve **Edison's direct current** (DC) generators and motors, which were then in widespread use for lighting and power distribution. **Tesla** worked tirelessly on the project, and eventually developed an **alternating current** (AC) motor that was far more efficient than Edison's DC technology. However, **Edison** was skeptical of AC power and refused to invest in it, leading Tesla to leave Edison's employ and strike out on his own. Despite his success with **AC technology**, Tesla faced numerous challenges in bringing it to market. **Edison** and his allies launched a vicious smear campaign against AC power, spreading misinformation and fear about its safety and reliability. **Edison** even went so far as to publicly electrocute animals with **AC power** in an attempt to discredit **Tesla's invention**. Despite these setbacks, **Tesla** continued to pursue his work on AC power, and eventually secured funding from George Westinghouse to build power stations and transmission lines that would bring AC power to the masses. However, even as **Tesla's star** was on the rise, he continued to face setbacks and betrayals. In 1895, **Tesla's laboratory** in New York City burned down, destroying years of research and development work. Tesla was devastated by the loss and struggled to rebuild his life and career in the aftermath. Later, **Tesla** would experience further betrayals at the hands of former collaborators and business partners. In the early 20th century, **Tesla** worked with financier **J.P. Morgan** to build the **Wardenclyffe Tower**, a massive wireless communication and power transmission project that was intended to revolutionize the world's communication and energy systems. However, **Morgan** soon grew impatient with Tesla's progress and demanded that the project be scaled back and refocused on communication rather than power transmission. **Tesla** reluctantly agreed, but the project ultimately ran out of funding before it could be completed, leaving **Tesla** deeply in debt and unable to pursue his research. Throughout his life, Tesla also struggled with personal and emotional setbacks. He was famously a recluse who had few close personal relationships, and his eccentricities and idiosyncrasies often left him isolated and misunderstood. Despite these challenges, however, **Tesla** continued to innovate and push the boundaries of science and technology until his death in 1943. Although the fact that **Nikola Tesla** accomplished many wonderful things throughout his career, he also encountered several betrayals and failures that slowed him down and prevented him from moving forward. From **Edison's betrayal** to the **Wardenclyffe Tower project**, Tesla's life was marked by struggles and disappointments, but he remained committed to his work and his vision until the end. Today, **Tesla** is remembered as a pioneering genius whose ideas and inventions have had a profound impact on the modern world.



**A few meters away from the generator, Tesla is carrying a lamp, yet it keeps on shining!**



**Mark Twain in the laboratory of Nikola Tesla, early 1894**

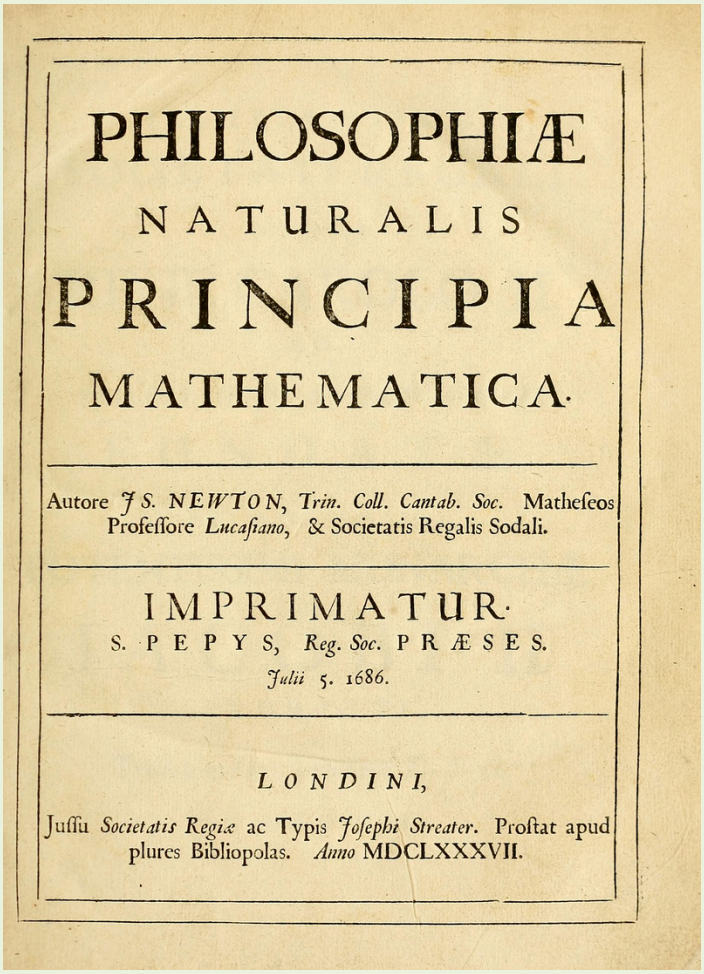


**The history of astronomy is a history of receding horizons.**

**Infrared image of Jupiter by James Webb Space Telescope, August 2022**

Equipped with his five senses, man explores the universe around him and calls the adventure Science.

- **ASTROMETRY** – How stars and other celestial bodies are positioned and move in space.
- **PLANETOLOGY** – How planets form in the solar systems including their physical feature, composition and dynamics in cosmic history.
- **EXOPLANETOLOGY** – How many and where extrasolar planets exist beyond our solar system.



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore *J S. NEWTON, Trin. Coll. Cantab. Soc.* Matheſeos Profeſſore *Lucaſiano*, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, *Reg. Soc.* PRÆSES.
*Julii* 5. 1686.

*LONDINI*,
Juſſu *Societatis Regiæ* ac Typis *Joſephi Streater*. Proſtat apud plures Bibliopolas. *Anno* MDCLXXXVII.

**"The Principia: Mathematical Principles of Natural Philosophy" is a work written by Sir Isaac Newton and published in 1687. It is considered one of the most important works in the history of science and is often referred to simply as "the Principia". The book lays out the fundamental principles of physics and mathematics that explain the behavior of objects in motion and the forces that act upon them. The three laws of motion that Newton formulated in the book are still widely used in physics today, and his law of universal gravitation describes the force that governs the motion of celestial bodies. The book also includes discussions of planetary motion, the nature of light, and the principles of calculus. The Principia is notable for its clear and concise mathematical language and the rigorous methods of investigation that it employs. It represents a landmark in the history of science and is regarded as one of the most important works of the Scientific Revolution.**

## ✓ The Tully-Fisher relation

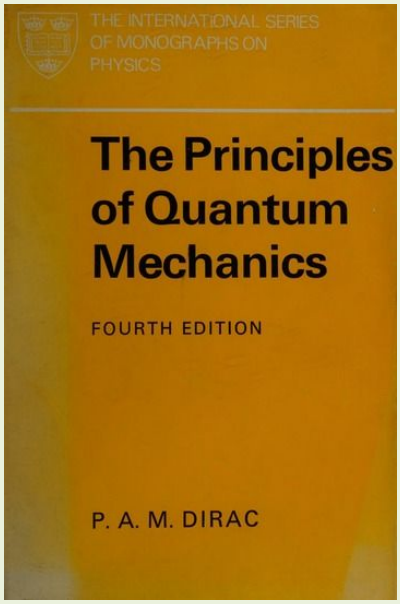
The **Tully-Fisher relation** is an empirical relationship between the luminosity and the rotational velocity of spiral galaxies. It was first discovered by astronomers **R. Brent Tully** and **J. Richard Fisher** in 1977. The Tully-Fisher relation states that the luminosity of a spiral galaxy is proportional to the fourth power of its maximum rotational velocity.

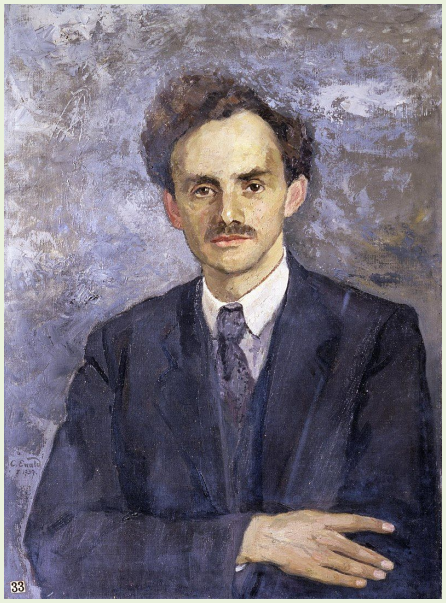
$$L \propto v^4$$

where L is the luminosity of the galaxy and v is its maximum rotational velocity. This means that more luminous galaxies have higher maximum rotational velocities.



**William Lassell** was a 19th-century English astronomer known for his significant contributions to the study of the solar system. He is particularly famous for his discovery of Triton, the largest moon of **Neptune**, in 1846, just days after the discovery of Neptune itself. **Lassell** also discovered two other **moons of Uranus**, **Ariel and Umbriel**, and he made important observations of **Saturn's moon**, **Hyperion**. In addition to his astronomical work, **Lassell** was a skilled engineer and constructed several telescopes, including the largest reflector of his time, which he used to make his groundbreaking discoveries.



**"Principles of Quantum Mechanics"** is a seminal book on the subject of **quantum mechanics** written by the British physicist **Paul Dirac**. The book was first published in 1930 and has since become a classic in the field. **Dirac's book** presents a mathematical framework for the theory of **quantum mechanics**, which describes the behavior of particles on a microscopic scale. He introduced the concept of wave functions, which describe the probability of finding a particle at a particular position and time. **Dirac's mathematical framework** is based on linear algebra and complex analysis, and it allows for the calculation of properties such as energy levels, transition probabilities, and scattering cross-sections. **"Principles of Quantum Mechanics"** also introduced the concept of the **Dirac equation**, which describes the behavior of relativistic particles, such as electrons, and predicts the existence of **antimatter. Dirac's work** played a crucial role in the development of modern theoretical physics and quantum field theory.



## Did you know?

According to some astronauts, the smell of space can be described as a combination of several scents, including seared steak, hot metal, and welding fumes. The reason for this unique odor is due to the high-energy particles and radiation present in the space environment. These particles interact with the materials on spacecraft, such as the metal exterior, which create volatile compounds that contribute to the smell.

## Galactic cannibalism

A process whereby a larger galaxy pulls material from or completely consumes a smaller one

The distance "**D**" at which a star has a parallax of "**p**" arcseconds can be calculated using the formula:

$$D = \frac{1}{p}$$

**For a star with a parallax of 0.1 arcsecond:**

$$D = \frac{1}{0.1 \text{ arcsecond}} = 10 \text{ parsecs}$$

A star at a distance of 10 parsecs has a parallax of 0.1 arcsecond.

**For a star with a parallax of 0.05 arcsecond:**

$$D = \frac{1}{0.05 \text{ arcsecond}} = 20 \text{ parsecs}$$

A star at a distance of 20 parsecs has a parallax of 0.05 arcsecond.



Given that the mass of the **white dwarf** is equal to the mass of the Sun ($1.98910 \times 10^{30}$ kg) and the radius of the white dwarf is equal to the radius of Earth ($6.3781 \times 10^{6}$ m), the acceleration of gravity at the surface of the white dwarf can be calculated using the equation:

$$g = \frac{GM}{R^2} = \frac{6.67384 \times 10^{-11}\ Nm^2/kg^2 \times\ 1.98910 \times 10^{30}\ kg}{(6.3781 \times 10^{6} m)^2}$$

$$g = 3.26324 \times 10^{6}\ m/s^2$$

Compare this to the acceleration of gravity at the surface of the Earth, which is 9.8 $m/s^2$. The acceleration of gravity on the white dwarf is approximately $3.3298 \times 10^{5}$ times greater than that on Earth.

## Work-Energy Theorem

The net work done on a particle is equal to the change in the particle's kinetic energy. If the net work done on a particle is positive, it will result in an increase in the particle's kinetic energy. On the other hand, if the net work done is negative, it will result in a decrease in the particle's kinetic energy.

**Some of the events that are most likely to result in a burst of gravitational waves are:**

- The merging of 2 neutron stars within a binary system as they orbit each other and gradually draw closer until they merge.
- The consumption of a neutron star by a black hole.
- The merging of 2 black holes.
- The explosion of a large star to create a black hole or neutron star.
- The initial tremor that marked the emergence of space and time, signaling the birth of the universe.

# ✓ Conclusion

Since the beginning of human civilization, one question that has baffled us is: **What makes the universe what it is?** More than 2000 years ago, Greek philosophers specifically raised this question. Many distinct individuals and groups have posed this question in various locations and at various times. Each group has come up with its own answers, which have taken the form of myths, prophecies, divine revelations, and accumulated histories. To address this question, which appears to be as old as human civilization itself, ancient civilisations all around the world recounted creation tales. The question is not just relevant to cosmology; in fact, it offers potential avenues for deciphering the underlying physics of our universe. Despite some significant achievements, not all problems have been resolved. The whole form of the laws of nature is not yet well understood. Without this knowledge, we are unsure of how far we can advance in our quest to comprehend the universe's future. Will it keep growing indefinitely? **Is inflation a natural law?** Are the electrons indivisible? Or will the universe eventually collapse? From where did we originate? When did we get here? What was the mechanism that led to the unusual and quick expansion of the human brain? Whether a neutrino is massive; if so, how much mass does it have? Does the success of the standard model indicate that we have finally discovered the most comprehensive theory to explain the universe? Theoretical developments and new observational findings are pouring in quickly. Dr. Science uses its laws, theories, and hypotheses to describe the universe. We'll be able to create more precise models of the universe's evolution as time goes on and our telescopes will discover more about the universe's nature as they advance.

Accepting that 99 percent of the universe cannot be observed is a bit challenging. In order to explain their cosmological observations over the past decades, astronomers and cosmologists have been forced to assume the existence of significant amounts of **"dark matter."** As to whether it is made up of neutrinos or other unusual exotic particles, scientists are still in the dark. **What is dark matter, then?** There are many researchers looking for answers, but none has found one yet. Understanding how everything came into being and how it acquired its current

elemental makeup is a fundamental problem in cosmology. The universe is a curious place, brimming with wonder and magnificence as well as a myriad of questions left unanswered and unexplained mysteries. No theory in science has ever been proven. Making disprovable predictions is where its power rests. **Cosmology** is a very dynamic and intriguing field that involves the scientific study of the big-scale characteristics of the universe as a whole. New understandings of the huge universe emerged at the beginning of the 20th century. The answers to the ages-old queries are nearing completion through observations of outer space. What brings us here? **What is our origin?** Are space and time fundamental or emergent? Is there a beginning to the cosmos, or is it eternal?



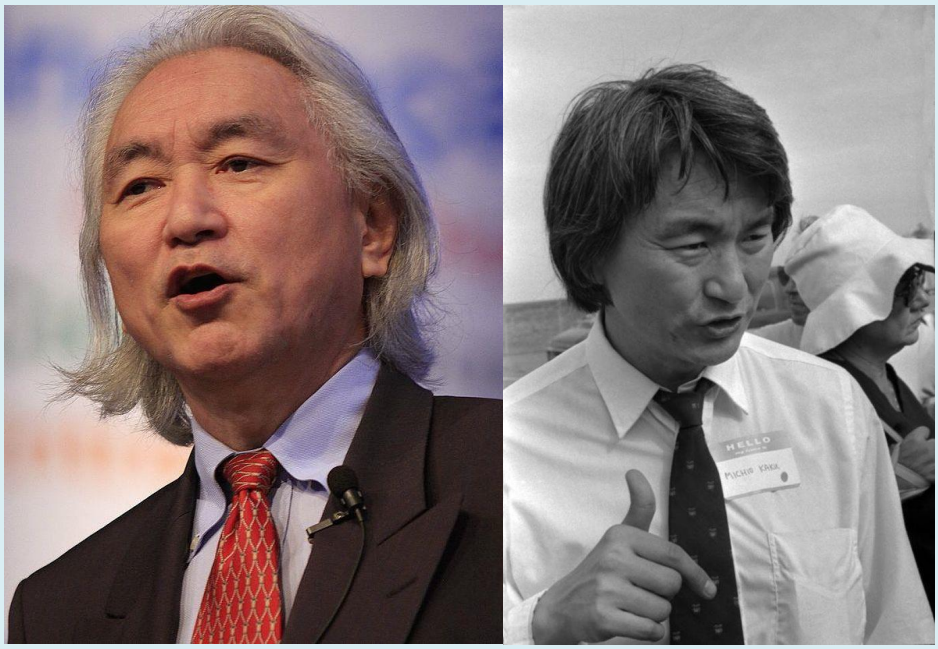
The **Big Bang theory** is a common name for the currently preferred explanation for the universe's creation. The Big Bang theory, according to which the known Universe is thought to have originated from a highly dense, extremely hot initial state − is based on **general relativity equations** that pertain to an expanding, homogeneous, and isotropic universe. This hypothesis additionally explains why galaxies recede according to **Hubble's law** and why the **cosmic microwave background radiation (whose spectrum is a perfect example of the black body spectrum)** is nearly homogeneous, with a black body temperature of 2.7 Kelvin. However, the Big Bang hypothesis is unable to explain certain issues: Initial density perturbation, or monopole, horizon, or flatness problems. The **theory of general relativity**, which views gravity as a manifestation of space-time geometry rather than a force, is universally acknowledged as the most magnificent of all scientific works. **Quantum Mechanics** and **General Relativity** do not work together. What about: **Before the Big Bang?** Neither theory can predict what happened. The unification of so called **weak nuclear forces** with the **Maxwell equations** is what known as the **Electroweak theory**. And the **electroweak theory** and **quantum chromodynamics** together constitutes the so called **Standard Model of particle physics**, which describes everything except gravity. The quest for a theory that can account for all elementary particle events, including their gravitational interaction, continues to be an uphill battle. It has been exciting to see progress made in this approach based on **string theory.** By considering an elementary particle as a little one-dimensional loop of vibrating string instead of a tiny point like objects, the string theory seeks to provide a more comprehensive explanation of nature. However, it is hard

to observe the strings with the available technology because they are so tiny—about $10^{-33}$ cm. As a result of the microscopic size of the strings, it is essentially impossible to test the theory's underlying assumptions or the math it explains. So far, **string theory** – which is regarded as the final theory of nature − has not been supported by any direct experimental data. Many physicists and scientists think it is an unsuccessful theory because of this. Even hundreds of years later, the desire to comprehend the interconnected nature of the universe and how we fit within it is still intense. In some ways, the universe does prove to be much bigger and more magnificent than our progenitors could have ever imagined, which makes puzzles about its beginnings and design much more appealing to research.

What about the quarks' substructure? Quarks also appear to be indivisible, like the electron. In fact, no current experiment has been able to show any evidence of the quarks' substructure. Trying to understand what is visible to us while pondering the nature of the cosmos. We are interested in discovering a **comprehensive theory of everything** that encompasses gravity, quantum mechanics, and all other physical interactions. If we succeed in this, we will truly comprehend the universe and our place in it. **Questions abound in cosmology.** There is always something new to learn in cosmology, even if it's just answering a question we've never thought to ask before. This is what keeps cosmology so exciting and intriguing.



# Famous Michio Kaku quotations that will broaden your cosmic outlook



**Michio Kaku's name** must have come up at least once in your life if you are a fan of modern astronomy. Michio Kaku is a co-founder of the string field theory and the author of several best-selling books, including Parallel Worlds, Beyond Einstein, and Hyperspace. He is currently pursuing the goal of unifying the four basic forces of nature into a single, comprehensive theory. At the moment, he is a lecturer at the CUNY Graduate Center and City College of New York. Therefore, if you enjoy popular science, you must respect this man. There is much to be learned from him and from his knowledge and wisdom. Here are some of the thinker's most insightful quotes that will motivate you to learn more about the universe's creation and functioning.

- The human brain has 100 billion neurons, each neuron connected to 10 thousand other neurons. Sitting on your shoulders is the most complicated object in the known universe.
- In string theory, all particles are vibrations on a tiny rubber band; physics is the harmonies on the string; chemistry is the melodies we play on vibrating strings; the

universe is a symphony of strings, and the 'Mind of God' is cosmic music resonating in 11 dimensional hyperspace.

- One in 200 stars has habitable Earth-like planets surrounding it – in the galaxy, half a billion stars have Earth-like planets going around them – that's huge, half a billion. So when we look at the night sky, it makes sense that someone is looking back at us.
- No one knows who wrote the laws of physics or where they come from. Science is based on testable, reproducible evidence, and so far we cannot test the universe before the Big Bang.
- In some sense, gravity does not exist; what moves the planets and the stars is the distortion of space and time.
- String theory is based on the simple idea that all the four forces of the universe: gravity, the electromagnetic force and the two nuclear forces, can be viewed, as music.
- The most complex object in the known universe: brain, only uses 20 watts of power. It would require a nuclear power plant to energize a computer the size of a city block to mimic your brain, and your brain does it with just 20 watts. So if someone calls you a dim bulb, that's a compliment.
- Math is discovered. To be invented requires an inventor, but math exists outside of humanity. But ultimately, the laws of the universe will be reduced down to a single equation, perhaps no more than one inch long. But leaves the final question, where did that one inch equation come from?
- It is often stated that of all the theories proposed in this century, the silliest is quantum theory. In fact, some say that the only thing that quantum theory has going for it is that it is unquestionably correct.
- When you come up with a theory, you fall in love with the beauty the simplicity and elegance of it. But then you have to get a sheet of paper and pencil and crack out all the details. Hundreds and hundreds of pages. Because you have to prove it.
- I began to realize something – to understand the future you have to understand physics. Physics of the last century gave us television, radio, microwaves, gave us the Internet, lasers, transistors, computers – all of that from physics.

- The idea that excites me the most concerns the two greatest puzzles in science: the origin of the universe, and the origin of consciousness. The origin of the universe is what I do for a living, working on string theory. But I am also fascinated by consciousness.
- Science is about principles. It's about concepts. It’s not about memorizing the parts of a flower. It helps to know some of these things, but if that’s all you do that’s not science, science is about principles and concepts.
- When we're born, we want to know why the stars shine. We want to know why the sun rises.
- Quantum entanglement allows you to send information faster than light, which upset Einstein. But Einstein has the last laugh. The information you send on quantum entanglement is random, useless information. So Einstein still has the last laugh.
- However, one new theory says that dark matter may be ordinary matter in a parallel universe. If a galaxy is hovering above in another dimension, we would not be able to see it. It would be invisible, yet we would feel its gravity. Hence, it might explain dark matter.
- Technologies that may be realized in centuries or millennium include: warp drive, traveling faster than the speed of light, parallel universes; are there other parallel dimensions and parallel realities? Time travel that we mentioned and going to the stars.
- Our best shot at finding life in our solar system might be to look at the moons of Jupiter and Saturn. Mars, increasingly, looks like a dead planet. But the oceans beneath the ice cover of the moons of Jupiter and Saturn may actually have more liquid water than the oceans of Earth.
- An event horizon, or the point of no return, is only a byproduct of the bending of space. However, electricity and magnetism, by themselves, have no event horizon. It gets complicated, however, if a black hole has charge, and then this new solution does have an event horizon.
- I agree, along with Carl Sagan, that we should eventually become a two planet species. Life is too precious to place on a single planet.

- We physicists know that the brain is a milliwatt transmitter of radio. We have computers that can decipher much of this gibberish coming from our brain and we could then use that to control computers.
- Sooner or later, we will face a catastrophic threat from space. Of all the possible threats, only a gigantic asteroid hit can destroy the entire planet. If we prepare now, we better our odds of survival. The dinosaurs never knew what hit them.
- A hydrogen bomb, for me, was puny compared to the Big Bang – the creation of the universe. That's what I really wanted to work on – the nature of the universe itself, and that's what I do for a living.
- No matter how beautiful the theory, one irritating fact can dismiss the entire formulism, so it has to be proven.
- I hope we find evidence of dark matter in the lab and in outer space. This would go a long way to proving the correctness of string theory, which is what I do for a living. That is my day job. So string theory is a potentially experimentally verifiable theory.
- We believe that black holes collapse to rings hitting very fast. If you follow through the ring you don't die. The mathematics says you fall straight through, perhaps to another universe.
- We are not at the end but at the beginning of a new physics. But whatever we find, there will always be new horizons continually awaiting us.
- Physics is often stranger than science fiction, and I think science fiction takes its cues from physics: higher dimensions, wormholes, the warping of space and time, stuff like that.
- I think a colony in space will take much longer than sci fiction writers think. It costs $10,000 to put a pound of anything into near earth orbit. That is your weight in gold. It costs about $100,000 a pound to put you on the moon. And it costs $1,000,000 a pound to put you on Mars.
- You cannot create new science unless you realise where the old science leaves off and new science begins, and science fiction forces us to confront this.
- Chances are, when we meet intelligent life forms in outer space they're going to be descended from predators.

- The best theory comes from string theory, which states that dark matter is nothing but a higher vibration of the string. We are, in some sense, the lowest octave of a vibrating string.
- According to Einstein, there is no gravitational pull. The earth warps the space-time continuum around our bodies, so space itself pushes us down to the floor. Thus, it is the presence of matter that warps space around it, giving us the illusion that there is a gravitational force pulling on neighboring objects.
- These parallel universes are not ghost worlds with an ephemeral existence; within each universe, we have the appearance of solid objects and concrete events as real and as objective as any.
- The quantum theory is based on the idea that there is a probability that all possible events, no matter how fantastic or silly, might occur.
- Because both quantum theory and Einstein's theory of gravity are united in ten-dimensional space, we expect that the question of time travel will be settled decisively by the hyperspace theory. As in the case of wormholes and dimensional windows, the final chapter will be written when we incorporate the full power of the hyperspace theory.
- Max Planck once remarked, "Science cannot solve the ultimate mystery of Nature." And it is because in the last analysis we ourselves are part of the mystery we are trying to solve.
- We have not yet figured out why there is more matter than antimatter in the universe. Only one ten-billionth of the original matter in the early universe survived this explosion, and we are part of it. The leading theory is that something violated the perfect symmetry between matter and antimatter at the Big Bang, but we don't know what it is. There is a Nobel Prize waiting for the enterprising individual who can solve this problem.
- One consequence of this formulation is that a physical principle that unites many smaller physical theories must automatically unite many seemingly unrelated branches of mathematics. This is precisely what string theory accomplishes. In fact, of all physical theories, string theory unites by far the largest number of branches of mathematics into a single coherent picture. Perhaps one of the by-products of the physicists' quest for unification will be the unification of mathematics as well.

- As all matter is crushed in the final moments before doomsday, intelligent life forms may be able to tunnel into higher-dimensional space or an alternative universe, avoiding the seemingly inevitable death of our universe.
- Physicists believe that at the instant of the Big Bang, the universe was in perfect symmetry and there was an equal amount of matter and antimatter. If so, the annihilation between the two would have been perfect and complete, and the universe should be made of pure radiation. Yet here we are, made of matter, which should not be around anymore. Our very existence defies modern physics.
- Nobel laureate Richard Feynman was fond of saying that no one really understands the quantum theory. Ironically, although the quantum theory is the most successful theory ever proposed by the human mind.
- Given that humanity must one day flee the solar system to the nearby stars to survive, or perish, the question is: how will we get there? The nearest star system, Alpha Centauri, is over 4 light-years away. Conventional chemical propulsion rockets, the workhorses of the current space program, barely reach 40,000 miles per hour. At that speed it would take 70,000 years just to visit the nearest star.
- And at the speed of light, you have taken the fastest possible journey to the stars. From your point of view, the trip is instantaneous.
- For the ten-dimensional universe, however, there are apparently millions of ways in which to curl up. To calculate which state the ten-dimensional universe prefers, we need to solve the field theory of strings using the theory of phase transitions, the most difficult problem in quantum theory.
- In other words, positive matter and energy that we see in stars can warp space-time so that it perfectly describes the motion of heavenly bodies. But negative matter and energy warp space-time in bizarre ways, creating an antigravitational force that can stabilize wormholes and prevent them from collapsing and propel warp bubbles to faster-than-light velocities by compressing space-time in front of them.
- Stephen Hawking has proven a general theorem stating that all solutions of Einstein's equations that allow faster-than-light travel must involve negative matter or energy.

# Best Cosmology Books of All Time:



- **A Brief History of Time**

  Book by Stephen Hawking

- **Cosmos**

  Book by Carl Sagan

- **The Fabric of the Cosmos**

  Book by Brian Greene

- **The Elegant Universe**

  Book by Brian Greene

- **The Big Picture: On the Origins of Life, Meaning, and the Universe Itself**

  Book by Sean Carroll

- **A Universe from Nothing: Why There Is Something Rather Than Nothing?**

  Book by Lawrence M. Krauss

- **The First Three Minutes: A Modern View of the Origin of the Universe**

  Book by Steven Weinberg

- **A Short History of Nearly Everything**

Book by Bill Bryson

- **The Grand Design**

  Book by Stephen Hawking

- **Death by Black Hole: And Other Cosmic Quandaries**

  Book by Neil deGrasse Tyson

- **Pale Blue Dot: A Vision of the Human Future in Space**

  Book by Carl Sagan

- **The Hidden Reality: Parallel Universes and the Deep Laws of the Cosmos**

  Book by Brian Greene

- **The Universe in a Nutshell**

  Book by Stephen Hawking

- **Astrophysics for People in a Hurry**

  Book by Neil deGrasse Tyson

- **Parallel Worlds: A Journey through Creation, Higher Dimensions, and the Future of the Cosmos**

  Book by Michio Kaku

- **Big Bang: The Origin of the Universe**

  Book by Simon Singh

- **Our Mathematical Universe: My Quest for the Ultimate Nature of Reality**

  Book by Max Tegmark

- **A Briefer History of Time**

Book by Stephen Hawking, Leonard Mlodinow

- **Reality Is Not What It Seems: The Journey to Quantum Gravity**

  Book by Carlo Rovelli, Simon Carnell, Erica Segre

- **Einstein: His Life and Universe**

  Book by Walter Isaacson

- **Black Holes and Time Warps: Einstein's Outrageous Legacy**

  Book by Kip S. Thorne, Stephen Hawking

- **The Demon-haunted World: Science As a Candle in the Dark**

  Book by Carl Sagan

- **Origins: Fourteen Billion Years of Cosmic Evolution**

  Book by Neil deGrasse Tyson, Vikas Adam, et al

- **The Theory of Everything: The Origin and Fate of the Universe**

  Book by Stephen Hawking

- **Brief Answers to the Big Questions**

  Book by Stephen Hawking

- **Black Holes and Baby Universes**

  Book by Stephen Hawking

- **The Black Hole War: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics**

  Book by Leonard Susskind

- **The Varieties of Scientific Experience: A Personal View of the Search for God**

Book by Carl Sagan, Ann Druyan

- **Hyperspace: A Scientific Odyssey Through Parallel Universes, Time Warps, and the Tenth Dimension**

  Book by Michio Kaku

- **Just Six Numbers: The Deep Forces That Shape the Universe**

  Book by Martin Rees

- **The Inflationary Universe: The Quest for a New Theory of Cosmic Origins**

  Book by Alan Guth

- **Coming of Age in the Milky Way**

  Book by Timothy Ferris

- **From Eternity to Here: The Quest for the Ultimate Theory of Time**

  Book by Sean Carroll

- **Seven Brief Lessons on Physics**

  Book by Carlo Rovelli

- **Billions and Billions: Thoughts on Life and Death at the Brink of the Millennium**

  Book by Carl Sagan

- **The Life of the Cosmos**

  Book by Lee Smolin

- **The 4% Universe: Dark Matter, Dark Energy, and the Race to Discover the Rest of Reality**

  Book by Richard Panek

- **Welcome to the Universe: An Astrophysical Tour**

  Book by Neil deGrasse Tyson

- **The Holographic Universe: The Revolutionary Theory of Reality**

  Book by Michael Talbot

- **The Road to Reality: A Complete Guide to the Laws of the Universe**

  Book by Roger Penrose

- **The Structure of Scientific Revolutions**

  Book by Thomas S. Kuhn and Ian Hacking

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**Thank you!**

Have you ever wondered what the ultimate question is? The one question that, if answered, would reveal the secrets of the universe? In this book, the author takes you on a journey to the edge of the universe, exploring the latest scientific theories about the origins, structure, and fate of our cosmos.

Along the way, you'll learn about the Big Bang, dark matter, dark energy, black holes, string theory, and other mind-bending concepts. You'll also meet the brilliant scientists who have dedicated their lives to unravelling the mysteries of the universe.

This thought-provoking book seamlessly weaves together the realms of mathematics, cosmology, and philosophy to unravel the profound enigmas that shroud our universe. It's also a personal journey of discovery, as the author shares his own passion for mathematics and his quest to find the ultimate question.

Whether you're a math whiz or a complete novice, you'll find something to enjoy in this book. It's a fascinating read that will challenge your mind and expand your horizons.

Here are some of the topics covered in the book:

The history of astronomy and cosmology
The laws of physics and their implications for the universe
The Big Bang and the evolution of the universe
Dark matter and dark energy
Black holes and other exotic objects
String theory and other unified theories of physics
The ultimate question and the search for meaning

The book is written in a clear and engaging style, and it's packed with interesting facts and insights. It's a must-read for anyone who's curious about the universe and the quest to find its ultimate secrets.

